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N. J. Agri. Experiment Station
Bulletin

no. 348, 1921

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MOSQUITOES OF NEW JERSEY AND THEIR CONTROL

NEW JERSEY

AGRICULTURAL

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BULLETIN 348

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ERRATA

Page 127—"*Aedes grossbecki* D. & K." should read "*Psorophora discolor* Coq."

Page 142—"*Aedes abserratus* Felt" should read "*Culex territans* Wlk." For description, see page 153.

Page 153—"*Culex territans* Wlk." should read "*Aedes abserratus* Felt." For description, see page 142.

NEW JERSEY
AGRICULTURAL EXPERIMENT STATIONS

BULLETIN 348

THE MOSQUITOES OF NEW JERSEY AND THEIR CONTROL

THOMAS J. HEADLEE, PH.D.

JANUARY 1, 1921

Introduction

The supply of Bulletin 276, which bears this title, is exhausted and the advance in knowledge of the subject is so large as to forbid the mere reprinting of the matter contained. In view of the steady demand for a publication of this sort, it seems necessary to prepare a revision.

As stated in Bulletin 276, it is proposed to prepare a brief, plain, and reasonably accurate statement of the main points involved in mosquito control. In a work of this sort, it is necessary to present the recognition marks, the importance, the seasonal life history of the more important species, then to discuss the underlying principles of control work, and for the sake of completeness to submit a list and illustrations of the other species that may be met. The nomenclature adopted is that proposed by Howard, Dyar, and Knab in their "Mosquitoes of North America, Central America and the West Indies."

More than forty different species of mosquitoes are known to occur in New Jersey, but fortunately only eight or ten of them can

be classified as first-class pests. New Jersey's mosquito problem differs from that of inland states primarily by reason of the prevalence of the far-flying species which breed on the salt marsh. It differs from that of most other coastal states, which have extensive salt marshes and lie in about the same latitude, in that at the northern end of its marshes is located an unusually dense population consisting of people drawn by business opportunities from all parts of the United States.

Roughly speaking, the species of importance may be grouped as follows: (1) the salt-marsh breeding species; (2) the woodland pool species (3) the fresh-water swamp species; (4) the malarial species; (5) the house-mosquito species. The first group covers in its distribution a coastal strip of varying width, involving more than three-fourths the population. The second group occurs throughout the northern half of the state wherever woodland pools are found. The fresh-water swamp species are found throughout the state wherever the cedar-swamp water is absent, but as a matter of act, are largely confined to the northern half where the soil is not sandy. The malarial species are more variable, *punctipennis* being found throughout, *quadrimaculatus* in limited areas throughout the northern half, and *crucians* only in the southeastern corner. The house mosquito is found everywhere throughout the state always occurring in the neighborhood of human habitation. It must be understood that these statements refer to general occurrence and do not mean that occasional specimens may not be found outside the territory allotted to the species to which they belong.

Furthermore, it should be recognized that species vary in abundance from year to year. A species which this year is scarce and almost negligible may next year be very abundant and a most serious pest. In the course of the last eight seasons the writer has seen the fresh-water swamp mosquito (*Aedes sylvestris*) rise in the northern part of the state to the position of the dominant form and then sink into comparative insignificance. The exact cause of this variation is not known but it is assumed that natural enemies or climate or both are responsible. Likewise, any of the free-biting species which at present occur in only negligible numbers might rapidly increase to proportions of a serious pest. The man, therefore, who would be successful as a mosquito fighter must know not only the ordinary economic species but must be able to recognize the less common and usually non-economic forms.

General Life Habits

The mosquito passes through four stages of existence: adult, egg, larva, and pupa.

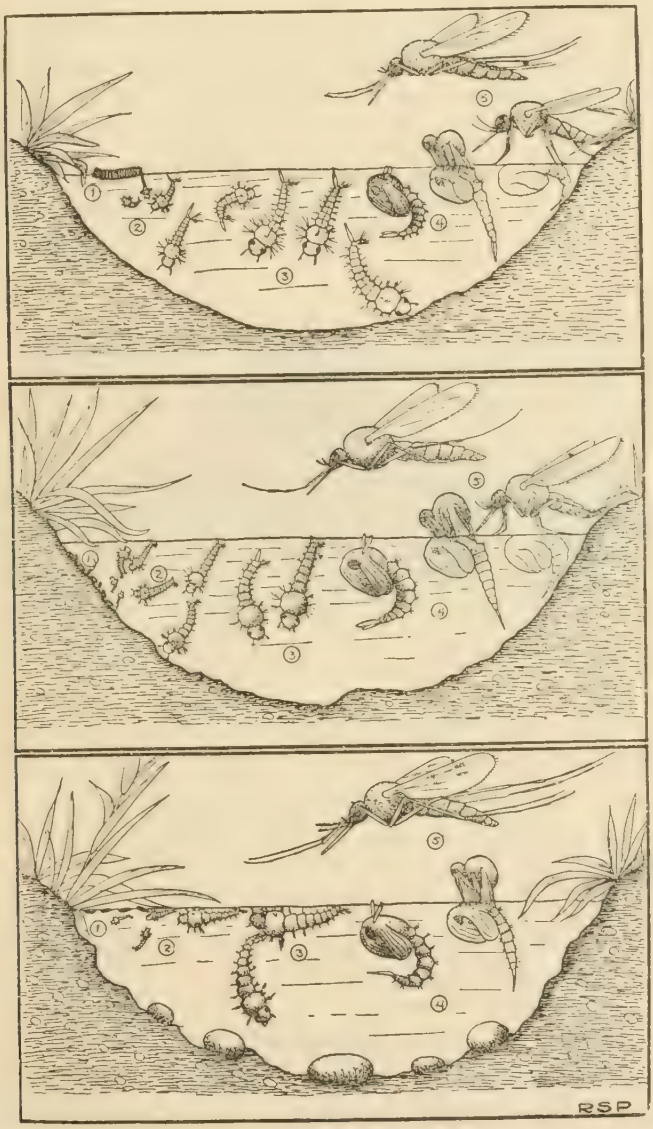


Fig. 1. Diagrammatic Life History of Three Typical Species—House of Mosquito, Salt-Marsh Mosquito, and Malarial Mosquito.

1, egg; 2, newly hatched larva; 3, developed larva; 4, pupa; 5, adult.

While with the adult we are all familiar, our acquaintance includes only such of the females as approach us for blood-sucking purposes. Those females that feed upon the blood of wild animals,

the nectar of plants and other plant juices, and the males, are practically never seen. The male may easily be distinguished from the female by the fact that its antennæ are very feathery. Only the female bites.

Eggs are laid on water or in the moist mud. In a longer or shorter time, depending on temperature and moisture, the egg is burst open and the wriggler emerges. In a longer or shorter time, depending on temperature and food supply (organic matter of various sorts), the wriggler reaches maturity and transforms to the pupa. The pupa can move rather freely but takes no food. Within the pupal skin, changes go on that transform the wriggler into a winged adult.

Fig. 2. Mosquito filling herself with blood. "It is the blood hunger of the mosquito that renders it an economic species."

The length of time necessary to pass from egg to adult depends on the species and on the temperature. The shortest time is about 8 days. The winter is passed in the egg, larva or adult stages. The number of broods depends on the species and the temperature, and ranges from one to many.

It is the blood hunger of the mosquito that renders it an economic species. This blood hunger induces the mosquito to follow and bite us, even under great difficulties.

How a Mosquito Bites

As soon as a mosquito settles upon the skin she begins the process of piercing it. The end of the beak is set against the surface and the lancets, which it shelters, begin to drive their way in. As they penetrate more and more deeply the beak covering bends at or near the middle permitting the head, without itself entering the wound, to come closer and closer to the skin.

The beak covering, which is the only member of the mouth appendages seen by the ordinary observer, corresponds to the labium or

the lower lip of the chewing insect. It is grooved lengthwise along its upper surface and forms a trough in which the delicate piercing lancets lie and by which they are protected from harm.

The lancets consist of six parts. The upper is a compound structure representing the *labrum,* or upper lip, and the *epipharynx* of the chewing insect. The *epipharynx* is grooved lengthwise of its lower surface in such a fashion as to form a complete tube when the *hypopharynx* is laid against it from below. The *hypopharynx* is a slender, flattened piece that fits closely against the open groove of the *epipharynx.* Through the tube thus formed the victim's blood is drawn into the mosquito's digestive tract. The next pair of lancets are slender, sharp pointed rods which correspond to the *mandibles,* or primary jaws, of chewing insects. The next pair of lancets, which correspond to the *maxillae,* or secondary jaws, of chewing insects, are also slender and pointed, but have slightly enlarged barbed ends. Almost if not quite coincidently with the moment that the skin is pierced, a small amount of saliva is injected through the epipharyngeal groove into the wound and suction begins very soon after that. The pumping portion, the foreintestine, regularly contracts and expands, drawing the blood from the victim into the mosquito's body. Unless disturbed, the creature will continue to feed until its abdomen is distended almost to bursting.

According to the late Dr. Smith, the mosquito requires about three minutes to complete its meal and then flies away to rest in some convenient spot until the blood is digested.

Structure and Classification

Speaking from the standpoint of mosquito suppression, it would be difficult to overestimate the value of a knowledge of mosquito species. Not only are the methods to be employed determined directly by the habits of the specific species, which are troublesome, but a true estimate of the results of the work cannot be reached without this knowledge. If the troublesome mosquitoes in a given locality are really salt-marsh species, a knowledge of that fact would prevent the useless expenditure of time and money on control of local breeding. If, in spite of all work which a municipality can do, it is overrun with mosquitoes, a knowledge of the species concerned will enable one to determine whether their presence means the failure of local work to control breeding or whether the municipality has a visitation of mosquitoes bred outside its boundaries.

Furthermore, a knowledge of the species giving trouble will enable one to trace them to the place in which they breed.

To obtain this necessary acquaintance with mosquito species, it is essential to become sufficiently familiar with the external anatomy of the larvae and of the mature insects to read and understand the artificial keys used in separating the different kinds.

In determining the species of mature mosquito caught at a certain point, the locality is of little aid, for many species fly or are wind-carried for long distances. It is necessary to become sufficiently familiar with the characteristic marks to determine the species by its appearance, regardless of the place in which it is found.

To a certain extent the same thing is true of classifying the larva. The inability of the larva to migrate is offset, to some extent, by the ubiquitous breeding habits of certain species. In general, however, in woodland pools the woodland species are likely to be found. In swamps the swamp species are likely to be prevalent. In reasonably clear water along the overgrown banks of streams, pools, and small lakes the malarial species are likely to breed. In stagnant pools in the open or about human habitations the house mosquitoes are likely to be prevalent. In the salt-marsh pools the salt-marsh species will be found. There is sufficient overlapping of one species on the territory of another to keep the student constantly on the lookout for the unexpected.

To sum it up, while the mosquito exterminator can place some reliance, in determining the species of larva, on the place in which it is found, the safe and satisfactory method is to become sufficiently familiar with the different common species to recognize them at sight.

Adult or perfect mosquitoes can be successfully classified only when they are killed without crushing. The condition best for determination obtains when the specimen has just emerged from the pupal shell and had time (24 hrs.) to harden. From that time forward, the markings decrease in clearness through fading and rubbing until, in specimens that have been on the wing seven or eight weeks, the really characteristic marks disappear, and determination becomes difficult if not impossible. Regardless of the period in adult life when the mosquito is caught for classification purposes, it should be placed, without touching with the hands, in a cyanide jar or other gas-killing apparatus. As soon as dead it should be emptied on a layer of very loose cotton. Unless it can be pinned within twenty-four hours it should be placed in a relaxing box

(moist chamber). When ready for pinning it should be laid on a smooth surface and pinned through the side of the thorax. The common method of pinning is to thrust the pin through the thorax from top to bottom, but the writer prefers the former because absolutely no handling of the specimen is required. By use of a spacer the insect should be slipped up the pin until it reaches a point just far enough below the head to enable the thumb and finger to grasp the head without touching any part of the insect. The date and locality label should then be slipped up the pin to a point just far enough below the insect to give a good clear view of all parts of the specimen. The completed specimen should then be thrust into the cork bottom of a tightly closing box and the box should be furnished with naphthalene to protect the mosquito against museum pests. In this way mosquito specimens may be preserved indefinitely. If storage is not desired the preparation may be stopped with the pinning.

Larval mosquitoes can be classified with certainty only as they are prepared for use under the microscope, or each individual separated out and allowed to breed through to an adult. In the field, larvae may be scooped up with a tumbler, or better still, with a small, fine-meshed net either of cloth or wire, and placed in vials filled with 80 per cent alcohol. In this form they will remain in condition for study for a long period. At any time specimens may be removed and mounted on a glass slide for study. Of course, still better conditions may be obtained by bringing the larvæ in alive and dropping them into hot absolute alcohol. After giving time for the alcohol to remove the water in their bodies (ten minutes when the number of specimens is small and the volume of alcohol large) they should be placed in xylol for clearing. When sufficiently clear they may be mounted directly on slides in Canada balsam. When properly carried out, this process gives specimens that will last indefinitely.

The mosquito's body, like that of most insects, is made up of three distinct regions—head, thorax and abdomen. The head is a globular object having: (1) a pair of eyes, one on each side of the head; (2) a pair of more (male) or less (female) feathery feelers, or *antennae;* (3) a pair of mouth feelers, or *palpi;* (4) a long prominent beak. The thorax is long, elliptical, and bears three pairs of legs on its lower surface and one pair of more or less transparent wings on its upper surface. The abdomen is long and narrow and composed of many plainly defined segments. It bears no appendages

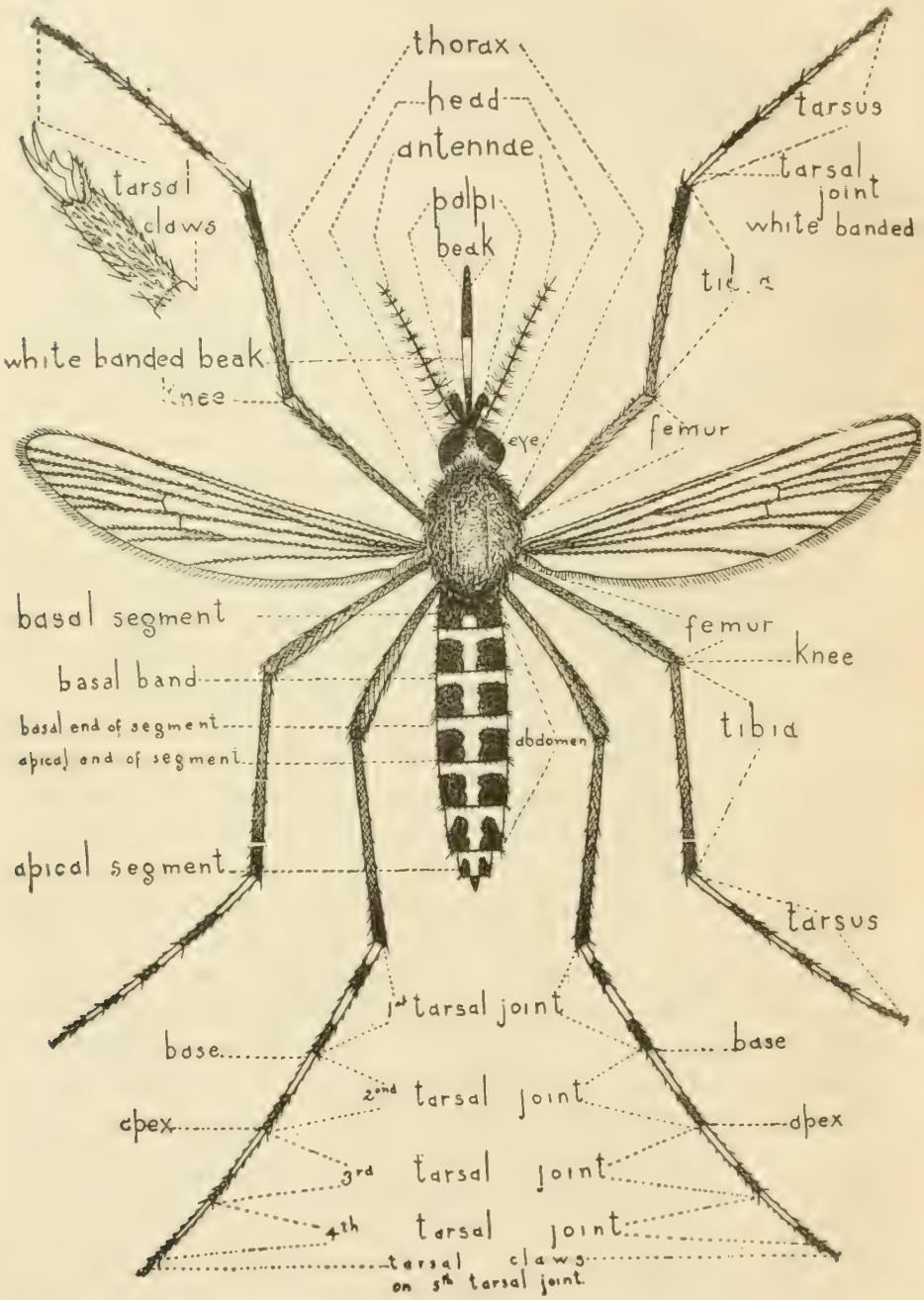


Fig. 3. Adult mosquito (*Aedes sollicitans* Wlk.) with parts named. (After John B. Smith).

other than certain ones connected with reproduction, and apparently they are not necessary in elementary classification.

Each leg consists of a small *coxa* and *trochanter* which, in figure 3, are so hidden by the body as not to show, a long *femur,* and equally long *tibia,* and a 5-jointed foot, or *tarsus.* The last joint is tipped with claws.

The wings have scales, generally collected along the veins. The color and arrangement of the scales determine the uniformity or spotted appearance of the wings.

When an infesting brood has been analyzed and traced to the place of origin as nearly as possible, it then becomes necessary to determine what species of wrigglers are found in the pools. If the species thus determined prove identical with those of principal members of the brood on the wing, the proof of source is complete. Furthermore, when wrigglers are found, it is not possible to judge whether they need treatment unless the kind of mosquitoes which they will produce is known. We must, therefore, be able to recognize the larvae as readily as the adults. To enable us to do this the external features must be discussed.

Like the adult, the wriggler exhibits the three divisions of the body—head, thorax and abdomen. The head bears a pair of eyes, a pair of antennae, and rotary mouth brushes. Each antenna exhibits a small bunch of hairs which has been designated as the antennal tuft. The thorax has various tufts of bristles scattered over it, known as the thoracic tufts. The abdomen consists of eight well-developed segments, each of which bears some tufts of bristles, known as the abdominal hair tufts. The eighth segment has grown a process known as the anal tube, or siphon, which bears a double row of spines on its posterior surface and has the opening of the breathing system at its tip. In nearly all species this tube is used to penetrate the water surface-film and to reach the atmospheric air. The ninth segment is small, bears a large group of bristles, the anal tuft, and some smaller tufts. The anal opening is situated at the outer end of this segment and the tracheal gills extend outward from this opening. On each side of the eighth segment there is a little patch of scales that is much used in classification.

For the determination of species of mosquitoes some sort of artificial key is necessary. The one which follows was prepared by Harry B. Weiss and Raymond S. Patterson. It has been used in the writer's classes for a number of years and has been found rather satisfactory. It has the fault, however, of not making adequate dis-

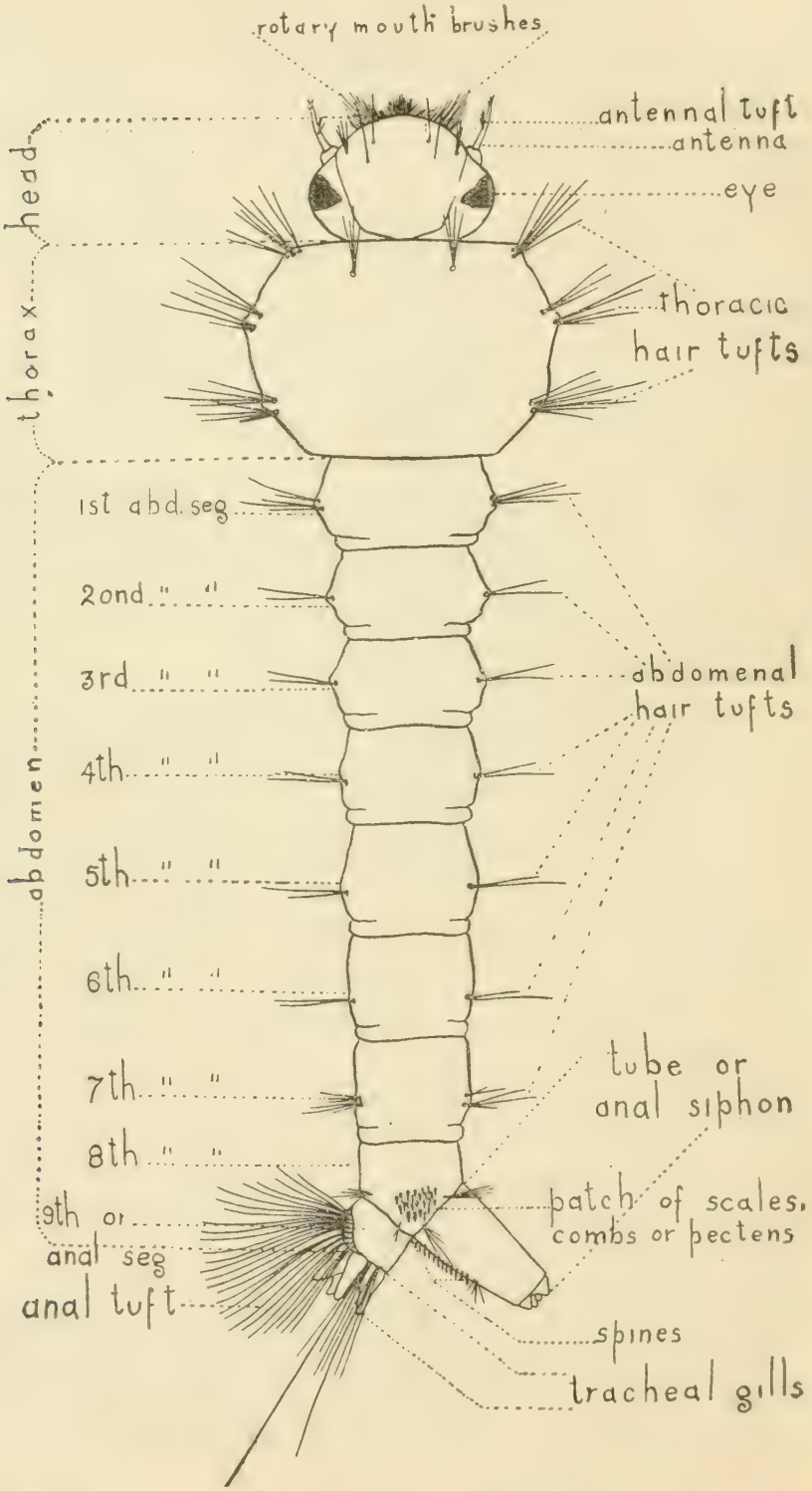


Fig. 4. Mosquito larva with parts named. (After John B. Smith).

tinction between the adult house mosquito (*Culex pipiens*) and the unbanded salt-marsh mosquito (*Culex salinarius*). It also fails to give adequate differences between the adult of the brown salt-marsh mosquito (*Aedes cantator*) and the brown woods mosquito (*Aedes stimulans*). The same may be said of it for the larvæ of mottled winged *anopheles (Anopheles punctipennis)* and the four-spotted winged *anopheles* (*Anopheles quadrimaculatus*). It is proposed to remedy these defects, which have been revealed by the practical work, by submitting a comparative list of characters of the species mentioned.

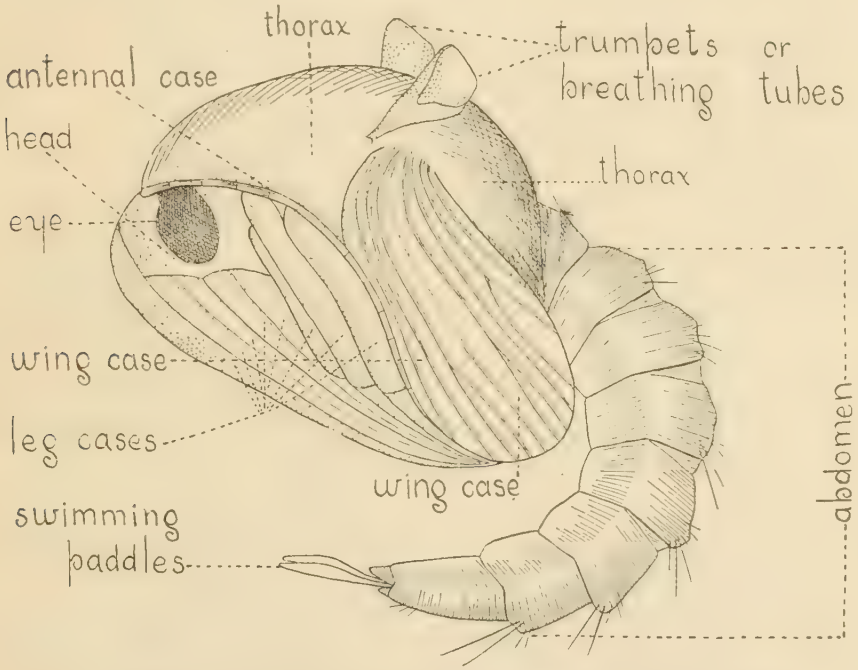


Fig. 5. Mosquito pupa with parts named. (After John B. Smith).

The practical work has shown the need of two types of keys—one of which shall enable the worker to determine almost any species taken in the state, and another which shall enable the observer with the least possible expenditure of time and effort, to determine the species that are commonly met with in the course of the practical control. The first type will necessarily involve the use of microscopic characters and is intended primarily for laboratory use, while the second should involve characters which can be determined by the eye, aided by an ordinary hand lens, and is intended for use in the field. The former type of key will be given first and the latter second.

Table to Determine Species of Mosquitoes

Series X in which the wings are spotted.

Palpi uniformly dark brown.

Wings with 2 white spots on the front margin of the wing; last vein white with black ends.....*Anopheles punctipennis* Say. (p. 96)

Wings with 4 distinct brown spots; last vein wholly dark brown.....
Anopheles quadrimaculatus Say. (p. 100)

Three small spots, middle of wing; abdomen spotted with brown and yellowish white.....*Psorophora discolor* Coq. (p. 126)

Palpi white marked at base of joints; last vein white marked with three black spots.....*Anopheles crucians* Wied. (p. 95)

Palpi black with white tips.

Wings grayish with distinct white spot in middle; thorax black with narrow white lines.....*Orthopodomyia signifer* Coq. (p. 132)

Series Y in which the wings are not spotted.

A. In which the feet are white or yellowish banded.

I. The beak has a more or less distinct white band or ring at or near its middle.

a. The abdomen has a yellowish stripe down its middle, and sides of thorax are white below a black edging.....
Aedes sollicitans Wlk. (p. 31)

b. The abdomen has no yellowish stripe. Sides of thorax are not white.

1. A large blackish species with a narrow white band near the tip of the femur; the tibia white-spotted.....
Psorophora columbiae D. & K. (p. 124)

2. A large brown species with a lighter band near the tip of the posterior tibia, the latter not spotted.....
Mansonia perturbans Wlk. (p. 107)

3. A smaller, blackish species, without markings on femur or tibia.....*Aedes taeniorhynchus* Wied. (p. 35)

II. The beak is without band or ring; uniform in color.

a. The joints of the feet or tarsi are banded or ringed at base only.

1. An extremely large, brownish black species. Legs fringed with erect black scales.....*Psorophora ciliata* Fabr. (p. 120)

2. A very large species with very scaly wings, the sides of the thorax and bands of the abdomen and feet white.....
Aedes grossbecki D. & K. (p. 128)

3. Wings thickly clothed with mixed yellow and brown scales. Thorax with broad, brown central stripe. First tarsal segment of anterior legs not banded.....*Aedes fitchii* Felt. (p. 130)

4. A small dark species with lightly scaled wings; the white bands of the feet narrow; those of the abdomen nearly divided in the centre .....*Aedes sylvestris* Theob. (p. 104)

5. A small brown species with the hind tarsi wholly white.....
Aedes niveitarsis Coq. (p. 130)
This species is held by H. D. & K. to be an abberation of...
Aedes canadensis Theob. (p. 112)

6. A good-sized brown species, with the bandings yellowish rather

than white, those of the abdominal segments only a little or not at all notched at the middle; breeds on salt marshes only.....
Aedes cantator Coq. (p. 36)

7. Very much like the preceding; but the bands of the abdomen and feet are broader and somewhat lighter in color. Breeds only in fresh-water areas.....*Aedes stimulans* Wlk. (p. 115)
8. Very much like the two preceding; but thorax has a central brown stripe.....*Aedes abfitichii* Felt. (p. 118)

b. The joints of the hind feet at least are white-banded or ringed at both base and tip; while last joint of hind tarsi is usually entirely white.

1. A good-sized brown species, the thorax without lines or marks; bands of tarsal joints broad..*Aedes canadensis* Theob. (p. 112)
2. A small blackish species, with top of thorax covered with gray hair and a dark line down its centre; bands on tarsi are narrow and white.....*Aedes atropalpus* Coq. (p. 134)
3. A medium-sized species, easily recognized by the peculiar golden streaked appearance of the thorax..*Culex dyari* Coq. (p. 136)

c. All of last two tarsal joints and apex of middle joint white.

1. A large or medium-sized species, black with deep purple reflection.....*Psorophora sayi* D. & K. (p. 120)

B. In which the feet are uniform in color, not in any way marked or banded.

I. The thorax is marked in some way, with stripes or spots, or the sides are white or golden brown.

a. Species with longitudinal white or blue stripes.

1. There are 2 white longitudinal stripes; the species is of moderate size and blackish.....*Aedes trivittatus* Coq. (p. 144)
2. There is a well-defined broad central white band, and the top of the head is also white; else as before.....
Aedes atlanticus D. & K. (p. 140)
3. There is a diffuse white central stripe, not defined as before; a very small blackish species.....*Aedes dupreei* Coq. (p. 140)
4. There is a central metallic blue stripe; also blue spots. A small dark brown species ....*Uranotaenia sapphirina* O. S. (p. 155)

b. Species in which the thorax is yellowish, white or brown, leaving a blackish central stripe or two, usually not sharply defined; all of moderate size.

1. The thorax is yellowish; brownish abdomen with narrow white bands.....*Aedes hirsuteron* Theob. (p. 146)
2. The thorax is golden yellow. Abdomen almost black, with broad white bands.....*Aedes abserratus* Felt. (p. 142)
3. The thorax is very dark brown with pale yellowish scales at sides; abdomen with dirty white bands.*Aedes trivittatus* Coq. (p. 144)
This species is held by H. D. & K. to be an abberation of....
Aedes inconspicuus Gross. (p. 146)
4. The thorax is dark brown, with two pale yellowish spots on centre. Abdomen dark brown with white bands.....
Culex territans Wlk. (p. 154)

This species is held by H. D. & K. to be an abberation of....
Culex saxatilis Gross. (p. 153)

5. The thorax is brown; abdomen not banded, with a metallic silvery gray luster; legs cream-colored.....
Aedes pallidohirta Gross. (p. 150)
This species is held by H. D. & K. to be an abberation of....
Aedes fuscus O. S. (p. 151)
6. The thorax is golden brown; the abdomen not banded; legs black.....*Aedes aurifer* Coq. (p. 148)
7. The thorax is silvery white at the sides, not extending much on the upper surface, most of which is black. Abdomen not banded.
Aedes triseriatus Say. (p. 137)

c. Species in which the thorax is white-dotted only.
1. There are 2 small white dots on each side of the middle and a U-shaped white mark at the base; the abdomen is banded.
Aedes restuans Theob. (p. 87)

d. Species in which the entire under surface is silvery white or yellowish.
1. A small form having dorsal surface black; stripes on thorax irregular.....*Wycomyia smithii* Coq. (p. 159)

II. The thorax is without marks or ornamentation.

a. The segments of the abdomen are narrowly banded at their bases.
1. A small dark brown species; abdominal bands wider in the middle than at its sides except on the seventh segment, which usually has a narrow band, broad at sides.....*Aedes fuscus* O. S. (p. 151)
2. A moderate-sized brownish species, with the bands of the abdomen of moderate width.....*Culex pipiens* Linn. (p. 82)
3. A somewhat darker, longer-legged species, with very narrow regular abdominal bands.....*Culex salinarius* Coq. (p. 41)

b. The segments of the abdomen are narrowly banded at their apices only.
1. A small, slight, blackish species...*Culex territans* Wlk. (p. 153)

c. The abdomen has no bands or only the merest indication of them.
1. A uniformly dark brown species of moderate size.....
Culex melanurus Coq. (p. 155)
2. Species having thorax yellowish brown, somewhat polished, with a thin bluish gray frosting...*Anopheles barberi* Coq. (p. 119)

Table to Determine Mosquito Larvae

Antennae arising from the sides of the head; antennae not pendant 1

1. No siphon or breathing tube on eighth abdominal segment..*Anopheles* 2
A siphon or breathing tube on eighth abdominal segment..... 3

2. Antennae yellowish; tracheal gills moderate in size.....
A. punctipennis, (p. 96). *A. quadrimaculatus.* (p. 100)
Antennae shorter, brownish; tracheal gills short.....
A. crucians. (p. 95)

3. Hair tufts on thorax and abdomen simple, sparse or absent..... 4
Thorax and abdomen with star-shaped or stellate hair tufts.....
Uranotaenia sapphirina. (p. 155)

4. Abdomen with four tracheal gills at tip..... 5
Abdomen with two thracheal gills only; a small whitish species with head rounded and thorax subquadrate....*Wyeomyia smithii.* (p. 159)
5. Antennae arise from sdies of anterior part of head..... 6
Antennae arise from near middle of sides of head; the mouth brushes forming a club at sides of mouth; a very large species.....
Psorophora ciliata. (p. 120)
6. The scales of the eighth abdominal segment are separate..... 8
The scales of the eighth abdominal segment, 5 to 8 in number, are arranged on a band..... 7
The scales are replaced by a series of chitinous bars, arranged in a single row..... 22
7. The anal siphon is very large and stout, dilated centrally; antennae much longer than head, slender with an even outcurve or convexity.
Psorophora sayi. (p. 120)
The anal siphon, shorter, stout, dilated nearer the base; antennae nearly straight, slender, shorter than head..*Psorophora columbiae.* (p. 124)
The anal siphon is short, stubby, not dilated; antennae much longer than the head, very thick medially, bisinuate or with an outward and an incurve or convexity.....*Psorophora discolor.* (p. 126)
8. The scales are not more than 16 in number and form a small patch.. 9
The scales number 20 or more and form a large patch..... 12
9. Anal siphon of moderate length, three times as long as wide or longer.. 10
Anal siphon short, less than three times as long as wide..... 11
10. About 12 elongate scales in a single row; 12 to 16 siphonal spines, each with one moderate-sized tooth, and sometimes a few very small ones below it.....*Aedes fuscus.* (p. 151)
Scales 10-15, in partly double row, tapering apically; siphonal spines, 14-18, simple or with 2 or 3 teeth.....*Aedes sylvestris.* (p. 130)
Scales 7-12 in patch; a small translucent species, feeding at bottom; tracheal gills very long and slender.....*Aedes dupreei.* (p. 140)
Scales 6-7 arranged in a curve; tracheal gills long, slender uniformly tapering.....*Aedes abserratus.* (p. 142)
11. Stout black species, the thorax white-banded; antennal tuft composed of many hairs; tracheal gills very long..*Aedes atlanticus.* (p. 140)
An elongate slender gray species; antennal tuft a single bristle; tracheal gills short.....*Aedes triseriatus.* (p. 137)
A large, robust, light species; anal siphon bottle-shaped, outer half linear; anal gills slightly longer than width of ninth segment.....
Mansonia perturbans. (p. 107)
12. Anal siphon short, not much more than twice as long as broad..... 13
Anal siphon moderate, from 2½ to 3½ times as long as broad..... 15
Anal siphon long, not less than 4 times as long as broad..... 21
13. Stout compact larva; antennal tuft of several hairs..... 14
Long slender larva, antennal tuft of 1 or 2 hairs; 25 to 35 scales in patch; 17 to 21 siphonal spines with 2 or 3 long teeth at base.....
Aedes atropalpus. (p. 134)
14. Scales 14-22, with stout apical and slender lateral spines; 13 to 18

siphonal spines with 2 or 3 small teeth, sometimes simple; fresh water.....*Aedes trivittatus.* (p. 144)
Scales 16-22 with rounded apex and slender lateral spines; 12 to 16 siphonal spines, with 1 to 4 small teeth on both sides; head maculate; salt marsh.....*Aedes taeniorhynchus.* (p. 35)
Scales 20-40, with stout apical and slender lateral spines; 16 to 24 siphonal spines with 1 to 5 small teeth; head generally immaculate; salt marsh.....*Aedes sollicitans.* (p. 31)

15. Scales rather broad..... 16
Scales elongate..... 17

16. Scales 35-40, with 3 stout apical and smaller lateral spines; 16 to 20 siphonal spines with 1 to 3 small teeth; head maculate; salt-marsh breeder.....*Aedes cantator.* (p. 36)
Scales 25-50, with one very stout apical and slender lateral spine; 16 to 22 siphonal spines, with 1 or 2 large, and 4 to 6 smaller teeth on basal half; head immaculate; fresh-water form.....
Aedes stimulans. (p. 115)

17. Only the terminal segment with a dorsal plate or ring..... 18
Last two segments with dorsal plates; antennae very short.....
Orthopodomyia signifer. (p. 132)

18. Antenna not specially marked or colored..... 19
Antenna prominent, white at base, dark at tip..*Aedes aurifer.* (p. 148)

19. Moderate-sized species..... 20
Very large larva; scales 28-34, with long apical and slender lateral spines; siphonal spines 17-22 with 4 or 5 large teeth basally.....
Aedes grossbecki. (p. 146)

20. Scales 25-50, with short apical and very short lateral spines; siphonal spines 16-20, with 1 or 2 teeth at base, 1 usually very large.....
Aedes hirsuteron. (p. 146)
Scales 40-45, with 5 to 7 large apical and smaller lateral spines; 16 to 22 siphonal spines, with usually 1 or 2, rarely 3 or 4 small teeth.
Aedes trivittatus. (p. 144)
Scale 25-50, with small apical and smaller lateral spines; 16 to 24 siphonal spines, with 4 or 5 serrations on basal half; antenna dark at tip.....*Aedes canadensis.* (p. 112)

21. Antennal tuft above the middle.
Anal siphon of moderate length, sides a little inflated; tracheal gills moderately long.....*Culex pipiens.* (p. 82)
Anal siphon very long, rather slender, slightly tapering to tip; head narrower than thorax; tracheal gills short...*Culex salinarius.* (p. 41)
Anal siphon very long and slender; a little constricted centrally, head as wide as thorax; tracheal gills moderate or long.....
Culex territans. (p. 153)
Anal siphon very long, stout; tapering uniformly. Scales about 80.
Culex dyari. (p. 136)

Antennal tuft below middle.
Scales 24-30, antenna not arising from an offset.....
Aedes abfitchii. (p. 118)

Anal siphon of moderate length, tracheal gills rather long..... *Culex restuans.* (p. 87)

Anal siphon 5 times as long as widest diameter. Antennae dark at tip .....*Aedes fitchii.* (p. 130)

22. A bronzed brown larva, with rather long, moderately stout, black breathing tube.....*Culex melanurus.* (p. 155)

Character Differences Between AEDES STIMULANS (Female) and AEDES CANTATOR (Female)

Aedes stimulans	*Aedes cantator*
1. *Proboscis*: vestiture brownish-black intermixed with sordid white scales, especially beneath.	1. *Proboscis*: vestiture brownish-black.
2. *Palpi*: clothed with black scales, bases of joints with yellowish white scales.	2. *Palpi*: black scaled, tip minutely white.
3. *Tori*: brown and with a patch of small white scales on inner side.	3. *Tori*: pale yellow without, blackish within.
4. *Prothoracic lobes*: clothed with dull whitish scales and black bristles.	4. *Prothoracic lobes*: clothed with brown scales and black bristles.
5. *Mesonotum*: dark brown, disk clothed with rich bronzy brown scales, the anterior and lateral margins and the ante-scutellar space with sordid silvery scales.	5. *Mesonotum*: dark brown, with bright bronzy brown scales, yellowish about ante-scutellar space and a short stripe of light scales on either side of it.
6. *Scutellum*: clothed with pale sordid yellow-silvery scales, each lobe with a group of *black bristles.*	6. *Scutellum*: clothed with yellowish scales, each lobe with a group of *golden brown* bristles.
7. *Coxae*: pale brown.	7. *Coxae*: orcherous yellow.
8. *Wing Scales*: black with dull white ones intermixed, white scales predominant only on subcostal vein, black ones elsewhere.	8. *Wing Scales*: brownish black, those on costa and first vein with a blue reflection.
9. *Tibiae*: black and white spots intermixed.	9. *Tibiae*: small pale spot at base.
10. *Claws*: one tooth on each claw of hind tarsi.	10. *Claws*: claws of hind tarsi without teeth.

Probably the easiest way of determining to which of these species a specimen belongs is to examine first the claws of the hind tarsi. If there are *no* teeth on these claws the specimen is *cantator;* if teeth are present, it is *stimulans.*

Character Differences Between **CULEX PIPIENS (Female) and CULEX SANLINARIUS, Coq. (Female)**

Culex pipiens	*Culex salinarius*
1. *Proboscis*: vestiture brown, pale beneath, darker towards tip.	1. *Proboscis*: vestiture black, pale beneath.
2. *Scutellum*: tuft of golden-brown bristles on each lobe.	2. *Scutellum*: group of black bristles on each lobe.
3. *Abdomen*: each segment except the first with a basal transverse band of yellowish or whitish scales.	3. *Abdomen*: transverse bands of yellowish scales much narrower than in *pipiens*.

Character Differences (Larval) Between **ANOPHELES QUADRIMACULATUS and ANOPHELES PUNCTIPENNIS**

Anopheles quadrimaculatus	*Anopheles punctipennis*
Mandible: with 7 large branched hairs on dorsal aspect in a group and two smaller ones near them; with terminal dentition of 12 teeth, the upper 3, projected bearing the fourth, fifth and sixth on the lower declivity.	*Mandibles* with 7 large branched hairs on the dorsal aspect in a line, two smaller ones near them; with terminal dentition of 11 teeth, upper third and fourth produced.

Eye and Hand-lens Key to the Adult of the More Common Species

A. Palpi at least three-fourths the length of the beak.
  I. Wing mottled bearing one large rather distinct white spot.
    Anopheles punctipennis. (p. 96)
  II. Wing without white spot but with four fairly distinct blackish spots; the spots due to aggregation of scales.
    Anopheles quadrimaculatus. (p. 100)
  III. Wing without any of the spots mentioned but with decidedly blackish front edge; this appearance due to aggregation of scales along front edge ..... *Anopheles crucians.* (p. 95)
B. Palpi scarcely more than one-fourth the length of the beak.
  I. Feet without white or yellowish bands.
    1. Front edge of abdominal segments bordered by white bands.
      Culex pipiens. (p. 82)
      Culex salinarius. (p. 41)
    2. Back edge of abdominal segment bordered by white band which is narrow and sometimes broken..... *Culex territans.* (p. 154)
  II. Feet white or yellowish banded.
    1. Beak with white circular band.
      a. Edges of white band not sharp; rough scaly species with much white on legs and feet..... *Mansonia perturbans.* (p. 107)
      b. Edges of white band sharp.
        (1) Yellowish white band running lengthwise the upper surface of the abdomen; no white bands or sharply defined spots on the hind femur or tibia..... *Aedes sollicitans.* (p. 31)
        (2) No lengthwise median band; no spots on the hind femur or tibia; two white spots, one on each side of the dorsal aspect of each of the two abdominal segments before the last..... *Aedes taeniorhynchus.* (p. 35)
    2. Beak without circular band.
      a. Abdominal bands white and rather sharp edges; abdominal bands so strongly notched from the rear as to appear almost divided; tarsal bands not occurring on both ends of the same segment.
        Aedes sylvestris. (p. 104)
      b. Abdominal bands not so notched; white bands on both ends of the hind tarsal segments, the joint between the femur and the first tarsal segment being completely white and thus giving the characteristic "white knees" of this species.
        Aedes canadensis. (p. 112)
      c. Abdominal and tarsal bands yellowish, no sharp notching in former, tarsal bands on basal ends of segments only.
        Aedes cantator. (p. 36)
        Aedes stimulans. (p. 115)
        Aedes abfitchii. (p. 118)
  III. Very large; twice as long from head to tail as any other common species; legs conspicuously fringed with long hairs.
    .. *Psorophora ciliata.* (p. 120)

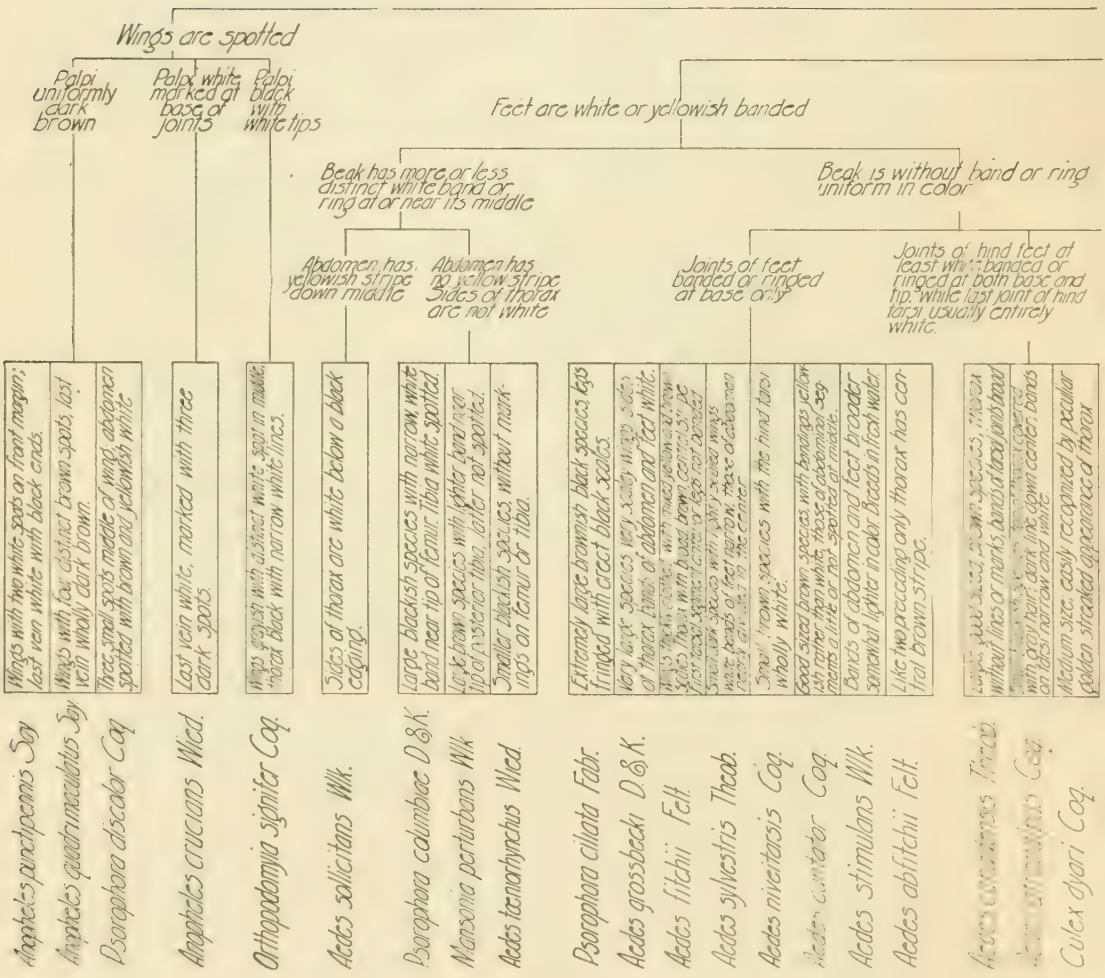
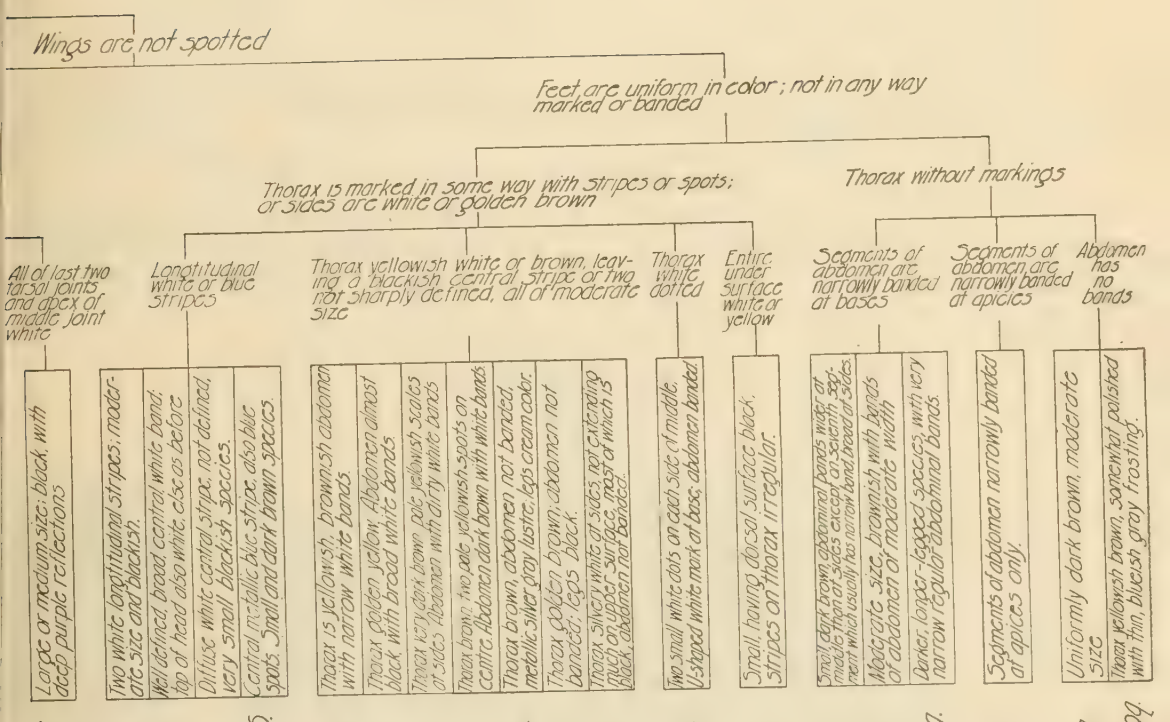

Wings are spotted
Palpi uniformly dark brown
Palpi white marked at base of joints
Palpi black with white tips
Feet are white or yellowish banded
Beak has more or less distinct white band or ring at or near its middle
Beak is without band or ring uniform in color
Abdomen has yellowish stripe down middle
Abdomen has no yellow stripe. Sides of thorax are not white
Joints of feet banded or ringed at base only
Joints of hind feet at least white banded or ringed at both base and tip, while last joint of hind tarsi usually entirely white.
Wings with two white spots on front margin; last vein white with black ends.
Wings with few distinct brown spots, last vein wholly dark brown.
Three small spots middle of wing, abdomen spotted with brown and yellowish white.
Last vein white, marked with three dark spots.
Wings grayish with distinct white spot in middle, costa black with narrow white lines.
Sides of thorax are white below a black caping.
Large blackish species with narrow white band near tip of femur, tibia white spotted.
Large brown species with lighter band near tip of posterior tibia, latter not spotted.
Smaller blackish species without markings on femur or tibia.
Extremely large brownish black species, legs fringed with erect black scales.
Very large species, very scaly wings, sides of thorax, bands of abdomen and feet white.
Wings with white spots, with male genitalia, with three pairs of appendages, or with two pairs of appendages and a pair of lobes; female with wings spotted, with or without white bands on feet, narrow, three abdominal bands, and a tuft in the center.
Small brown species with the hind tarsi wholly white.
Good sized brown species with bandings yellow or white, the latter on sides of abdomen. Leg marks white or not spotted or striate.
Bands of abdomen and feet broader
Somewhat lighter in color. Breeds in fresh water
Like the preceding, only thorax has central brown stripe.
Anopheles punctipennis Say
Anopheles quadrimaculatus Say
Psorophora discolor Coq.
Anopheles crucians Wied.
Orthopodomyia signifer Coq.
Aedes sollicitans Wlk.
Psorophora columbiae D. & K.
Mansonia perturbans Wlk.
Aedes taeniorhynchus Wied.
Psorophora ciliata Fabr.
Aedes grossbecki D. & K.
Aedes fitchii Felt
Aedes sylvestris Theob.
Aedes nigripes Coq.
Aedes cantator Coq.
Aedes stimulans Wlk.
Aedes abfitchii Felt
Culex pipiens Linn.
Culex quinquefasciatus Say
Culex tarsalis Coq.
Culex dyari Coq.

Diagram to Determine Species of Adult Mosquitoes.


Wings are not spotted
Feet are uniform in color; not in any way marked or banded
Thorax is marked in some way with stripes or spots; or sides are white or golden brown
Thorax without markings
All of last two tarsal joints and apex of middle joint white
Longitudinal white or blue stripes
Thorax yellowish white or brown, leaving a blackish central stripe or two not sharply defined, all of moderate size
Thorax white dotted
Entire under surface white or yellow
Segments of abdomen are narrowly banded at bases
Segments of abdomen are narrowly banded at apicies
Abdomen has no bands
Large or medium size; black with deep purple reflections
Two white longitudinal stripes; moderate size and blackish
Well defined, broad central white band; top of head also white, else as before
Diffuse white central stripe; not defined; very small blackish species.
Central metallic blue stripe, also blue spots. Small and dark brown species
Thorax is yellowish, brownish abdomen with narrow white bands
Thorax golden yellow. Abdomen almost black with broad white bands
Thorax very dark brown, pale yellowish scales or sides. Abdomen with dirty white bands
Thorax brown, two pale yellowish spots on centre. Abdomen dark brown with white bands
Thorax brown, abdomen not banded, metallic silver gray lustre. Legs cream color.
Thorax golden brown, abdomen not banded; legs black.
Thorax silvery white at sides, not extending much on upper surface, most of which is black, abdomen not banded.
Two small white dots on each side of middle. U shaped white mark at base, abdomen banded
Small, having discal surface black. Stripes on thorax irregular.
Small dark brown, abdominal bands wider at middle than at sides except on seventh segment which usually has narrow band at sides.
Moderate size, brownish, with bands of abdomen of moderate width
Darker, longer-legged species, with very narrow regular abdominal bands
Segments of abdomen narrowly banded at apices only.
Uniformly dark brown, moderate size
Thorax yellowish brown, somewhat polished with thin, bluish gray frosting.
Psorophora sayi D & K.
Aedes trivittatus Coq.
Aedes atlanticus D & K
Aedes dupreei Coq.
Uranotaenia sapphirina O.S.
Aedes hirsuteron Theob.
Aedes aboriratus Felt.
Aedes trivittatus Coq
(Aedes provocans Gross)
Culex territans Wlk.
(Culex sollicitans Gross)
Aedes pallidonirta Gross.
Aedes aurifer Coq.
Aedes triseriatus Say.
Aedes restuans Theob.
Wyeomyia smithii Coq.
Aedes fuscus O.S.
Culex pipiens Linn.
Culex salinarius Coq.
Culex territans Wlk.
Culex melanurus Coq
Anopheles barbari Coq.

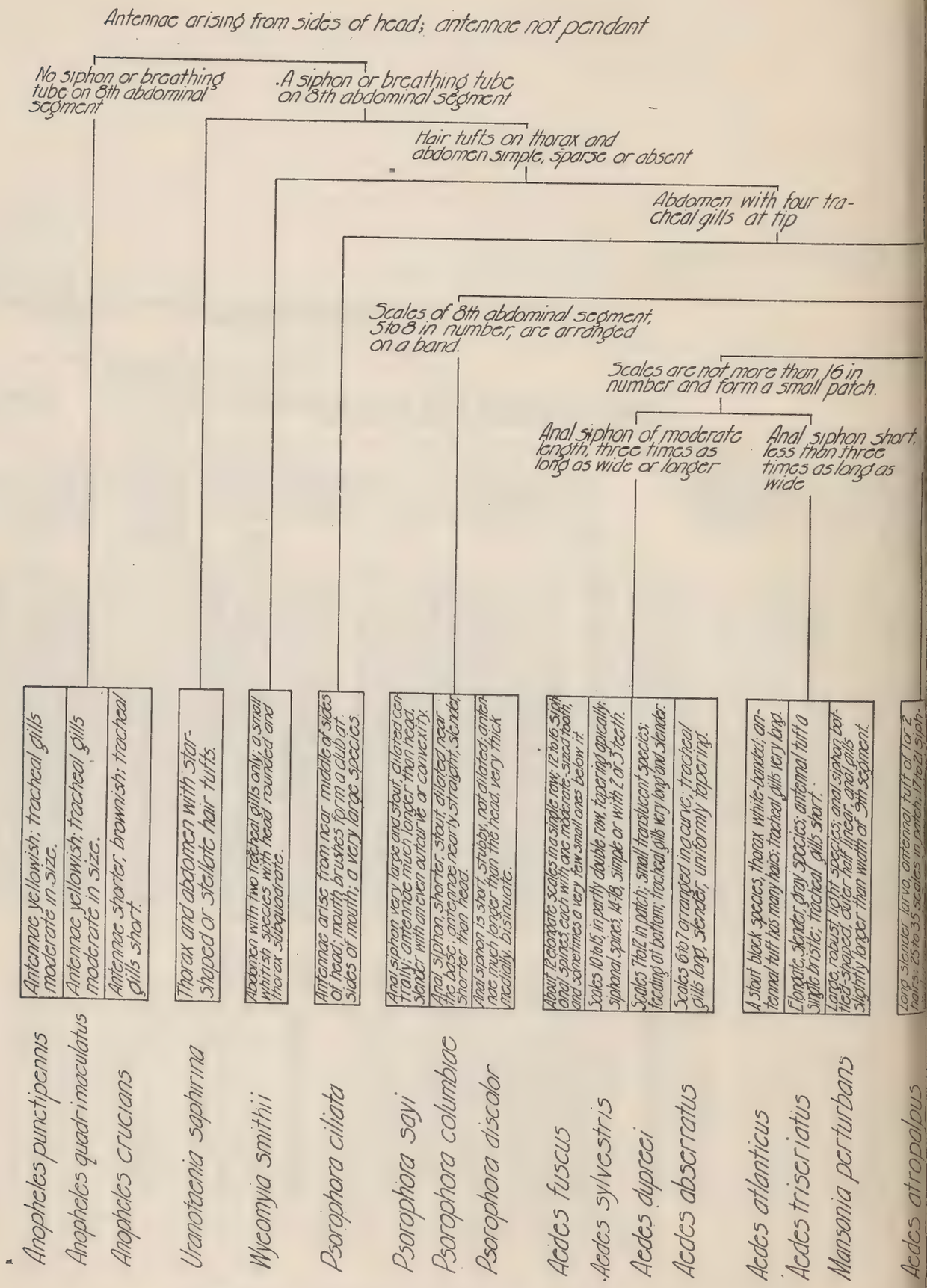
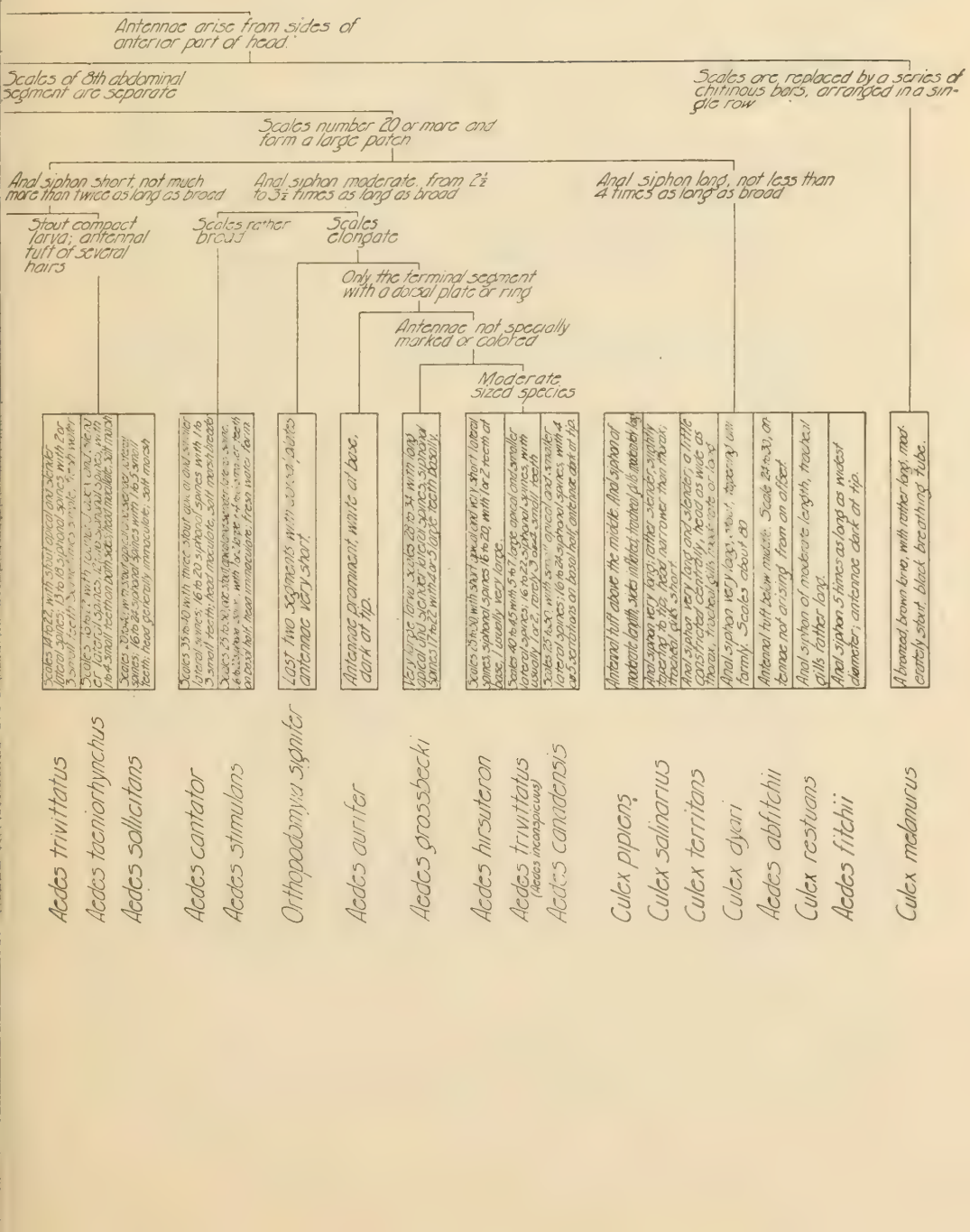

Antennae arising from sides of head; antennae not pendant
No siphon or breathing tube on 8th abdominal segment
A siphon or breathing tube on 8th abdominal segment
Hair tufts on thorax and abdomen simple, sparse or absent
Abdomen with four tracheal gills at tip
Scales of 8th abdominal segment, 5 to 8 in number, are arranged on a band.
Scales are not more than 16 in number and form a small patch.
Anal siphon of moderate length, three times as long as wide or longer
Anal siphon short, less than three times as long as wide
Antennae yellowish; tracheal gills moderate in size.
Antennae yellowish; tracheal gills moderate in size.
Antennae shorter, brownish; tracheal gills short.
Thorax and abdomen with star-shaped or stellate hair tufts.
Abdomen with two tracheal gills only; a small whitish species with head rounded and thorax subquadrate.
Antennae arise from near middle of sides of head; mouth brushes form a club at sides of mouth; a very large species.
Anal siphon very large and stout, dilated centrally; antennae much longer than head, slender with an even outcurve or convexity.
Anal siphon shorter, stout, dilated near the base; antennae nearly straight, slender, shorter than head.
Anal siphon is short, stubby, not dilated; antennae much longer than the head, very thick medially, bisinuate.
About 12 elongate scales in a single row; 12 to 16 slim anal spines each with one moderate-sized tooth, and sometimes a very few small ones below it.
Scales 10 to 15, in partly double row, tapering apically; siphonal spines 4 to 8, simple or with 1 or 2 teeth.
Scales 7 to 12 in patch; small translucent species; feeding on bottom; tracheal gills very long and slender.
Scales 6 to 7 arranged in curve; tracheal gills long, slender, uniformly tapering.
A stout black species; thorax white-banded; antennal tuft has many hairs; tracheal gills very long.
Elongate, slender, gray species; antennal tuft a single bristle; tracheal gills short.
Large, robust light species; anal siphon battledore-shaped, outer half linear; gill slightly longer than width of 9th segment.
Long slender larva, antennal tuft of 1 or 2 hairs; 2.5 to 3.5 scales in patch; 1 to 2 siph.
Anopheles punctipennis
Anopheles quadrimaculatus
Anopheles crucians
Uranotaenia sapphirina
Wyeomyia smithii
Psorophora ciliata
Psorophora sayi
Psorophora columbiae
Psorophora discolor
Aedes fuscus
Aedes sylvestris
Aedes dupreei
Aedes aberratus
Aedes atlanticus
Aedes triseriatus
Mansonia perturbans
Aedes atropalpus

Diagram to Determine Species of Mosquito Larvae.


Antennae arise from sides of anterior part of head.
Scales of 8th abdominal segment are separate
Scales are replaced by a series of chitinous bars, arranged in a single row
Scales number 20 or more and form a large patch
Anal siphon short, not much more than twice as long as broad
Anal siphon moderate, from 2½ to 3½ times as long as broad
Anal siphon long, not less than 4 times as long as broad
Stout compact larva; antennal tuft of several hairs
Scales rather broad
Scales elongate
Only the terminal segment with a dorsal plate or ring
Antennae not specially marked or colored
Moderate sized species
Lost, two segments with dorsal plates; antennae very short
Antennae prominent, white at base, dark at tip.
Very large species with short, broad scales
Scales 25 to 30 with short, broad very short lateral spines, siphonal spines 16 to 20, with 1 or 2 teeth at base, usually very large.
Scales 40 to 45 with 5 to 7 large apical and smaller lateral spines, 16 to 23 siphonal spines, with usually 1 or 2, rarely 3 or 4 small teeth
Scales 25 to 30 with small apical and smaller lateral spines; 16 to 18 siphonal spines, with 4 or 5 serrations on basal half, antennae dark at tip.
Antenal tuft above the middle. Anal siphon moderate length, side inflated, tracheal gills rather long.
Anal siphon very long, rather slender, slightly tapering to tip. Pecten narrower than in Aedes, tracheal gills short.
Anal siphon very long and slender, a little constricted centrally, head as wide as thorax, tracheal gills rudimentary or absent.
Anal siphon very large, stout, tapering uniformly. Scales about 80
Antennal tuft below middle. Scales 25 to 30, on tenae not arising from an atticet
Anal siphon of moderate length, tracheal gills rather long.
Anal siphon 5 times as long as widest diameter; antennae dark at tip.
A bronzed, brown larva, with rather long, moderately stout, black breathing tube.
Aedes trivittatus
Aedes taeniorhynchus
Aedes sollicitans
Aedes cantator
Aedes stimulans
Orthopodomyia signifer
Aedes aurifer
Aedes grossbecki
Aedes hirsuteron
Aedes trivittatus (Aedes incognitus)
Aedes canadensis
Culex pipiens
Culex salinarius
Culex territans
Culex dyari
Aedes abfitchii
Culex restuans
Aedes fitchii
Culex melanurus

Eye and Hand-lens Key to the Larvae of the More Common Species

A. Siphon or breathing tube so very short as to seem absent; larvae lie parallel with the surface of the water.

Anopheles punctipennis. (p. 96)
Anopheles quadrimaculatus. (p. 100)
Anopheles crucians. (p. 95)

B. Siphon or breathing tube distinctly present.

I. Antennae arising from near middle of sides of the head. Very large species.....*Psorophora ciliata.* (p. 120)

II. Antennae arising from sides of anterior of head.

1. Breathing tube sharp-pointed, spike-like.

Mansonia perturbans. (p. 107)

2. Breathing tube normal with a blunt end.

a. Found in fresh water; breathing tube medium length 2½ or 3 times as long as broad; head with 2 or 3 small colored patches, all in front of base of antennae.....*Aedes sylvestris.* (p. 104)

b. Found in fresh water; breathing tube 3½ times as long as broad; antennal tuft near the middle; head without colored patches.

Aedes stimulans. (p. 115)

c. Found in fresh water, woodland pools; breathing tube 3 times as long as broad; head with 3 colored patches, all back of base of antennae.....*Aedes canadensis.* (p. 112)

d. Found in fresh water; breathing tube 4 times as long as broad, slightly swollen at base..... *Culex pipiens.* (p. 82)

e. Found in brackish water; breathing tube fully 5 times as long as broad, tapering evenly from base to tip.

Culex salinarius. (p. 41)

f. Found in fresh water; breathing tube about 8 times as long as broad, slightly constricted at middle..*Culex territans.* (p. 153)

g. Found in fresh water; breathing tube about 3½ times as long as broad; antennal tuft decidedly before the middle; head with one larger and several small colored patches.

Aedes abfitchii. (p. 118)

h. Found in salt or brackish water; breathing tube hardly 2 times as long as broad; head hardly more than one-half width of thorax.....*Aedes sollicitans.* (p. 31)

i. Found in salt or brackish water; breathing tube hardly more than 1½ times as long as broad; head about two-thirds width of thorax.....*Aedes taeniorhynchus.* (p. 35)

j. Found in salt or brackish water; breathing tube a little less than 3 times as long as broad; head globular about one-half width of thorax.....*Aedes cantator.* (p. 36)

Mosquito Species

Economically Important

The Salt-Marsh Mosquito Group

Six species breed more or less in the brackish water of the salt marshes: *Anopheles quadrimaculatus* Say, *A. crucians* Wied., *Aedes sollicitans* Wlk., *A. taeniorhynchus* Wied., *A. cantator* Coq., and *Culex salinarius* Coq. The first is essentially a member of the malarial mosquito group and will be treated under that heading, the second breeds both in the salt marsh and in swampy areas inland; the other four breed exclusively on the salt marshes.

THE WHITE-BANDED SALT-MARSH MOSQUITO

(Aedes sollicitans Wlk.*)*

This species of mosquito has a combination of color markings seen in no other New Jersey species. A broad white band circles the beak; its feet are circled by broad white bands; yellowish white bands border the bases of the abdominal segments; a stripe of the same color extends lengthwise along the dorsal aspect of the abdomen and its thorax is golden yellow with silvery-white sides.

The stout compact larva is dirty gray or yellowish white in color and furnished with a breathing tube which is not more than twice as long as it is broad. Its antennae are not pendant and arise from the sides of the anterior part of the head. It has four tracheal gills. The scales are separate and form a large patch of twenty to forty on each side of the eighth abdominal segment. Its head is plain—practically without markings.

Importance

From the standpoint of territory covered, and the length of the season during which it is troublesome, this species is the most important of all the salt-marsh group. Appearing in early spring in South Jersey, it continues throughout the season and reaches its greatest abundance in August and September. Beginning in midsummer north of Sandy Hook, it soon becomes the prevailing salt-marsh form about the Raritan Bay, Arthur Kill and Newark Bay.

Bred solely in the waters of the salt marshes, it rises and makes its way inland for long distances—in some cases forty miles. In

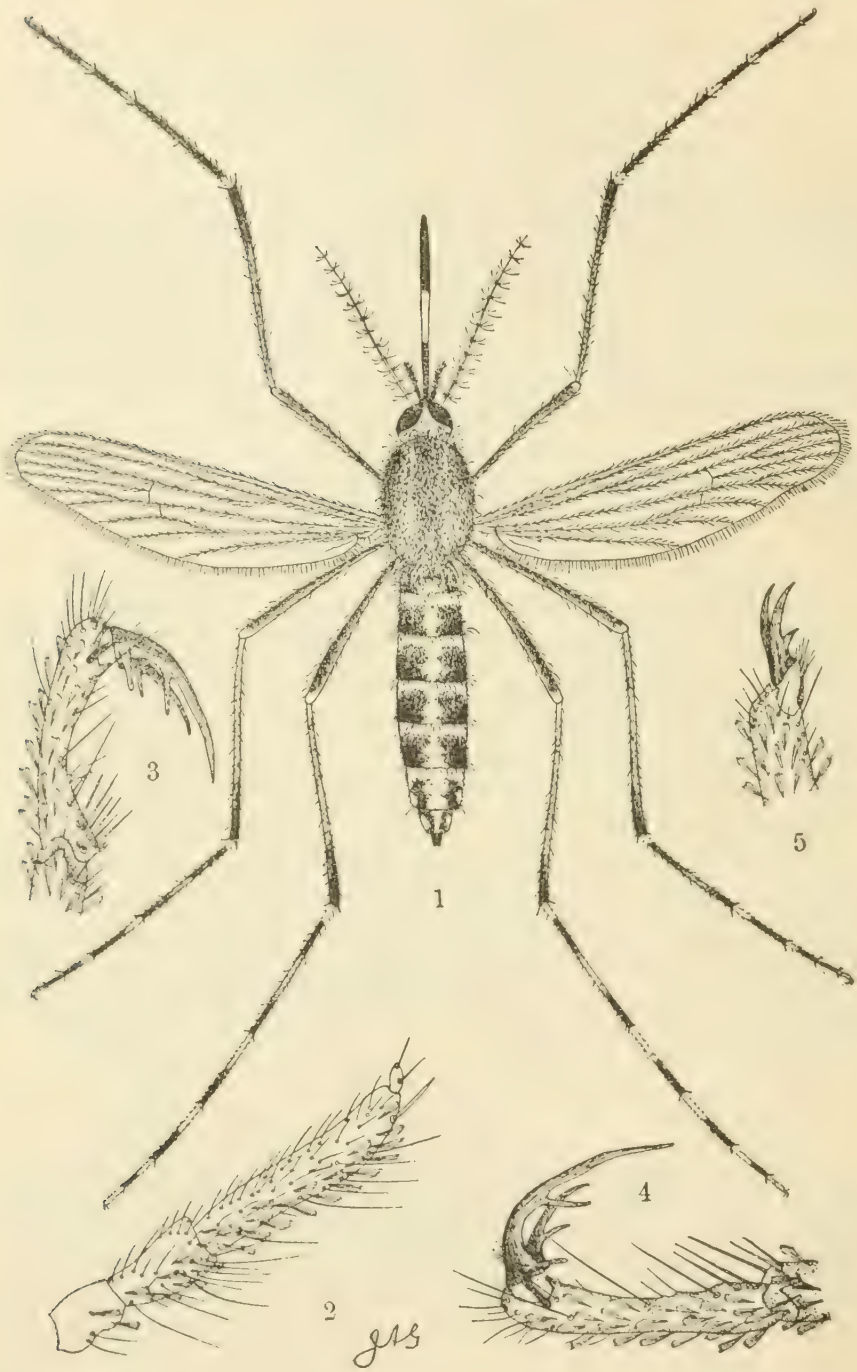


Fig. 6. Adult White-banded Salt-Marsh Mosquito. (After John B. Smith).
1, adult female; 2, palpus; 3, anterior, 4, median and 5, posterior claws of the male (much enlarged).

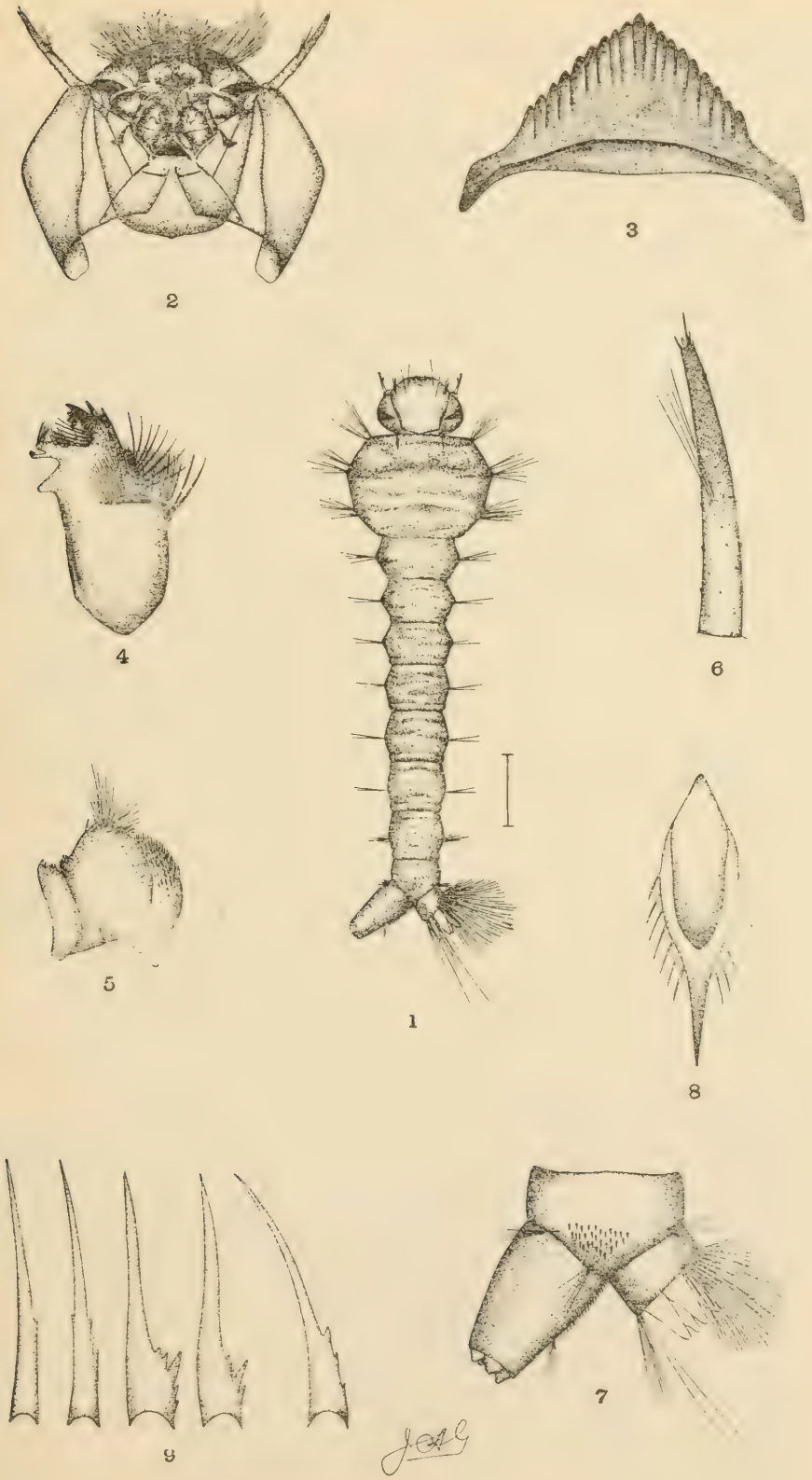


Fig. 7. Larva of White-banded Salt-Marsh Mosquito. (After John B. Smith).
1, larva; 2, head; 3, mentum; 4, mandible; 5, maxilla; 6, antenna; 7, terminal segments and siphon; 8, a single scale; 9, siphonal spines showing variation (all much enlarged).

good breeding seasons, from mid-summer on, the whole of Soutl Jersey, with the exception of the northwestern parts of Burlington, Camden, Gloucester, Cumberland and Salem counties, is infested by this species. This band of mosquito-infested territory shows the greatest number of mosquitoes nearest the marsh and a decrease in number as the observer goes farther and farther from it. Of course, modifications of this general condition are brought about by prevailing winds and the character of the plant growth.

So long as the sand strip bordering the ocean is swept by sea breezes this species of mosquito is not in evidence, but if the breeding is active when the winds blow from the marshes, the mosquitoes come in countless numbers, and human comfort for all out-of-doors and for many in-doors is at an end.

Literally millions of dollars invested in enterprises, which involved as a step necessary to success the bringing in of people from practically mosquito free places, have been lost. In many places attempts to develop tracts of land for summer-resort and for farming purposes have proven complete failures because of this mosquito. It is the greatest single factor now operative in South Jersey in depressing real estate values and preventing the proper development of that section of the state.

Life Habits

The winter is passed by this insect in the egg stage. The eggs, which are black in color, and spindle-shaped, lie in the mud of the salt marshes. They were deposited there the preceding season by the adult females. They occur in every part of the salt marsh and country adjacent thereto which was damp the preceding season when the female mosquitoes were on the wing and ready to oviposit.

Under favorable conditions, i. e., if covered with water, the eggs begin to hatch very early in March. Wrigglers have been found as early as March 5, although the temperature of the water at that time ranged from 42° to 50° F. Under such temperatures as this, larval growth is slow, requiring almost a month for its completion.

With the temperatures of mid-summer, larval development is much more rapid. A few hours after a dry salt meadow has been covered by tides or rain, the water left on it may be swarming with tiny wrigglers. A week will suffice to bring the larvae to the pupal stage, and 24 hours more may bring the emergence of the adults. The speed of development is directly correlated with temperature

and food supply. The higher the temperature and the more abundant the food supply, the shorter will be the period of development. Also it should be recognized that within ordinary outdoor limits, the higher the temperature the greater is the food supply.

There is not a regular succession of broods, as in most other insects. The marshes are full of eggs. In the summer season, submergence, whether by rains or tides, starts a brood which, unless destroyed by fish or by the drying up of the water, undergoes its transformations and gets on the wing, deposits its eggs and contributes its part to human discomfort. This process continues throughout the season from March to October.

If the eggs are water-covered within 24 hours of the time of placing they perish, but they may remain dry for three months or longer without losing vitality. When covered with water after remaining dry for a week or two, their hatching is a matter of minutes rather than hours.

Apparently, a considerable percentage of the eggs deposited during any one season fail to hatch during that season and remain in mud until the one following. By this provision of nature the salt marsh is always stocked with eggs, and the appearance of a brood is a matter of water covering, high temperature, and the absence of fish. If the water remains only long enough for the larvae to transform to pupae, the pupae will get enough moisture from the mud to exist for the 24 hours, at the end of which time many of them will produce adult mosquitoes.

The Small Salt-Marsh Mosquito

(*Aedes taeniorhynchus* Say.)

This species may be recognized by the following description. It is a small black mosquito with narrow white bands at the base of the abdominal segments, and with a narrow white band around the beak and around the base of each tarsal joint except the last, which is entirely white. The larva is very similar to *A. sollicitans,* but differs in that the head is usually marked with color.

While similar in habits to *A. sollicitans,* it does not fly so far over the upland. Along the South Jersey coast there are times when this species is just as abundant near the shore as *A. sollicitans.*

The Brown Salt-Marsh Mosquito

(Aedes cantator Coq.)

Recognition Marks

This species is much harder to characterize than the two preceding, but has the following fairly distinct characters: It is a large (¼ inch or more long), robust mosquito of a general brown color; the thorax is covered with distinct spiny hair; the tarsi show a white

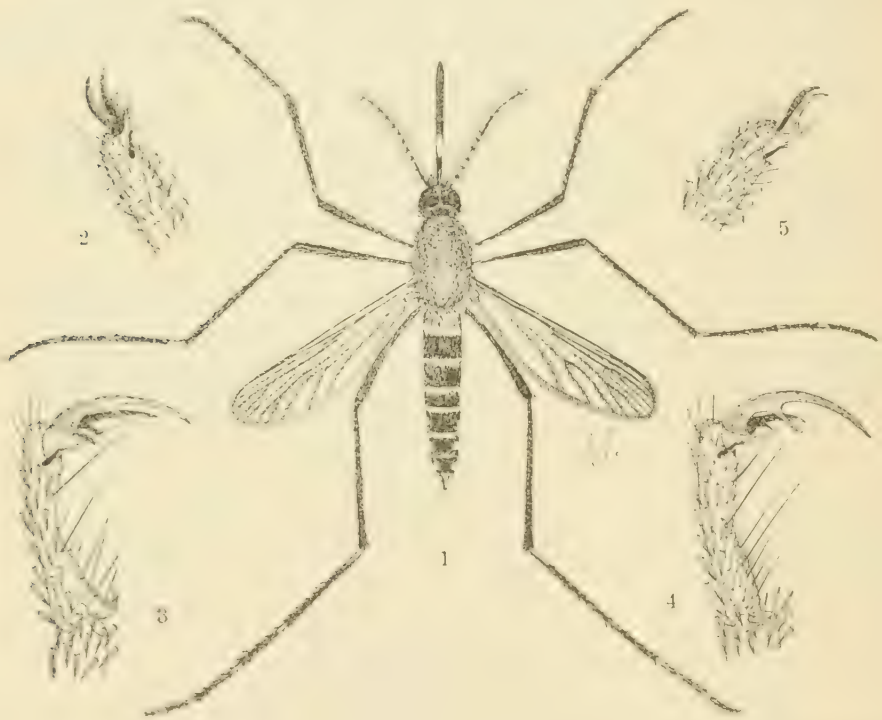


Fig. 8. Adult of the Small Salt-Marsh Mosquito. (After John B. Smith). 1, adult female; 2, anterior claws; 3, anterior; 4, median and 5, posterior claws of male (all much enlarged).

band at the base of each joint, but the bands are not well marked and merge gradually into the ground color; each abdominal segment shows a whitish band at its base, but the bands are rather indefinite and not constricted at the center. This species can be distinguished from the brown woods mosquito (*A. stimulans*) only by a careful comparison such as outlined on page 23.

The larva is dirty gray in color and has a breathing tube which is from 2½ to 3½ times as long as broad. Its antennae are not pendant and arise from the sides of the anterior part of the head. It has 4

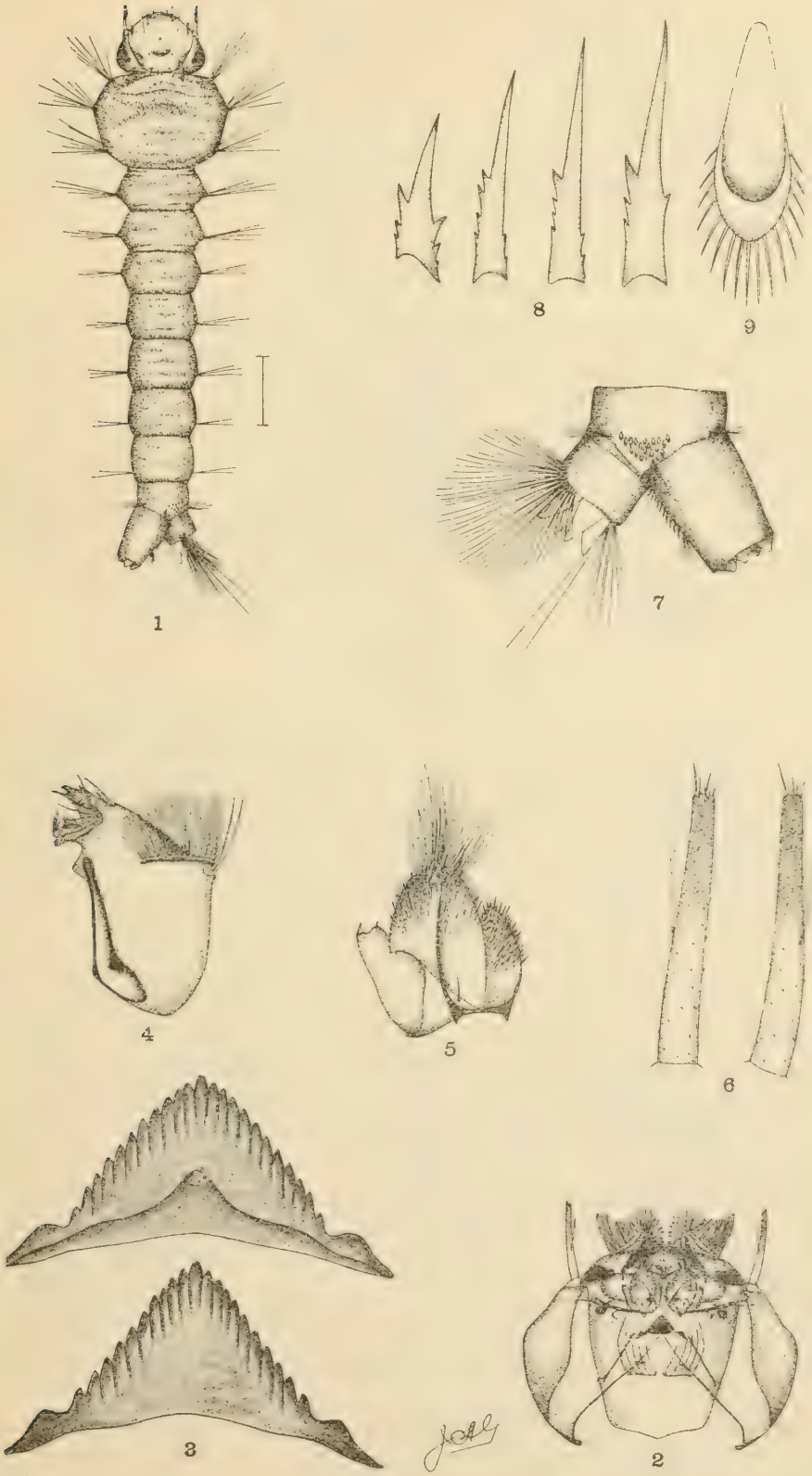


Fig. 9. Larva of the Small Salt-Marsh Mosquito. (After John B. Smith).

1, larva; 2, head from below; 3, mentum; 4, mandible; 5, maxilla; 6, antennae; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale of 8th segment (all much enlarged).

tracheal gills. The scales on each side of the eighth abdominal segment are broad, separate, 35 to 40 in number, and form a large patch. The head is marked with black spots.

Importance

A. cantator breeds abundantly from Cape May Point north, and during the first half of the season is the all-important salt-marsh mosquito in North Jersey. Until the drainage of the marshes where it bred, it came in hordes upon the cities of Elizabeth, Newark, Jersey City and various towns and villages lying between Raritan Bay, Arthur Kill and Newark Bay and the mountains. So far as our experience goes, it is now the only important salt-marsh mosquito which breeds on the northern three-fourths of the Hackensack Valley salt marsh.

Life Habits

The winter is passed in the egg stage in the mud in the marshes. As a rule, the eggs of this species appear to be laid nearer the upland and in rare instances on the upland itself. Larvae appear and develop in salt or fresh water or any mixture of the two.[1] In general, however, pools formed on the salt-marsh by rain-water or by drainage from the highlands seem most satisfactory to this species. The rest of its life history and development is the same as that of *A. sollicitans* and needs no further discussion.

Dr. Smith has the following to say about the distribution of *A. cantator*: "In New Jersey *cantator* dominates the Newark, Elizabeth and Raritan meadows early in the season. If the year is favorable, the early start will carry this dominance to mid-summer or even through the summer. At the Barnegat Bay shore *cantator* shares with *sollicitans* the early honors, but becomes steadily less as the season advances, leaving *sollicitans* in almost sole possession. At Atlantic City and Cape May I found no *cantator* during the period when they were swarming further north, though the species does occur there in small numbers throughout the summer. Mr. Brakeley's records show that they must have bred on the Mullica River marshes in greater numbers than *sollicitans* during the present

[1]This statement refers to conditions as they appear to the casual observer. As a matter of fact, both total lack of salinity and too high a degree of it appear to inhibit the development of the early stages.

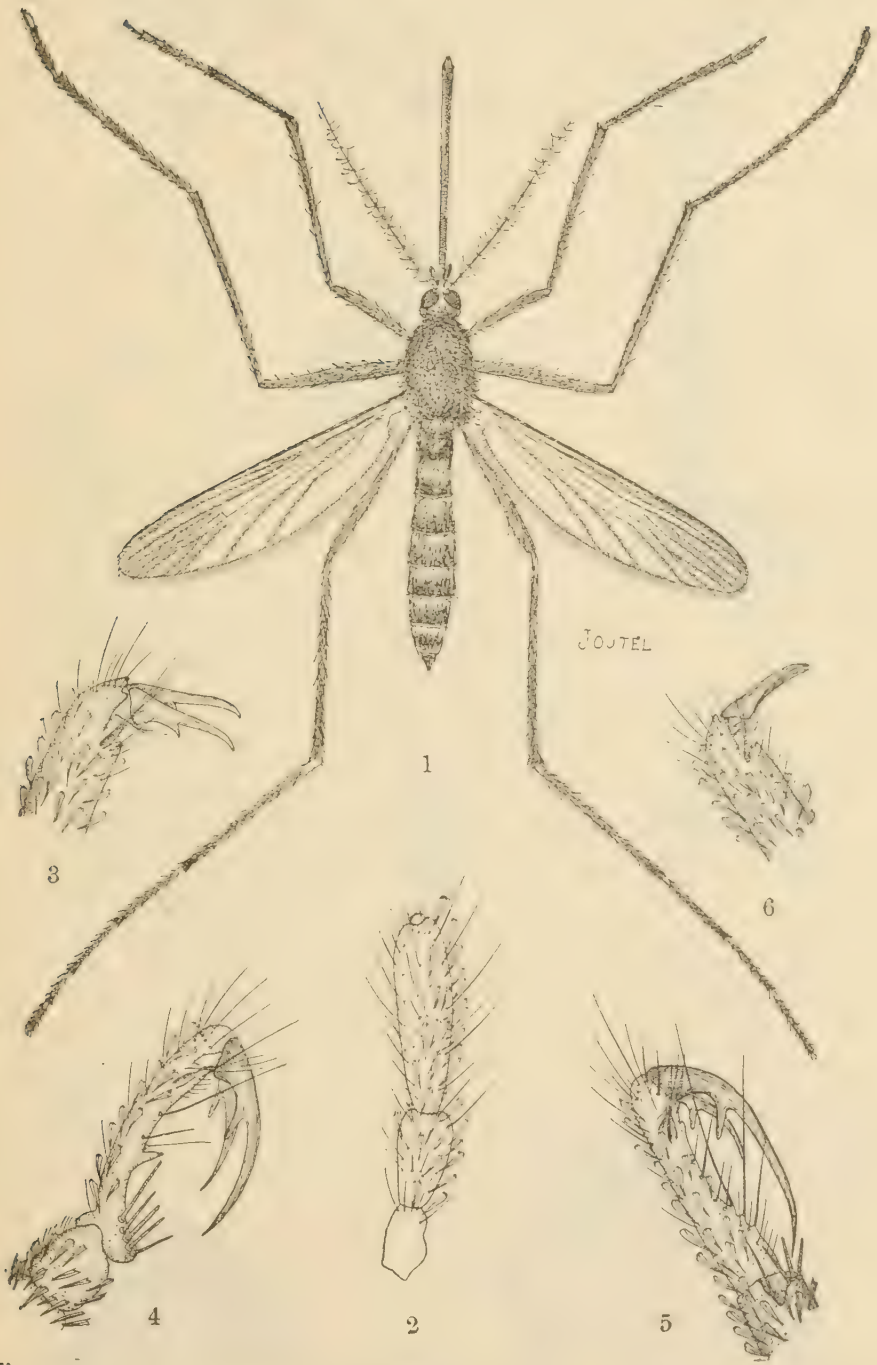


Fig. 10. Adult of the Brown Salt-Marsh Mosquito. (After John B. Smith).
1, adult female; 2, palpus and 3, anterior claws of same; 4, anterior, 5, median and 6, posterior claws of male (all much enlarged).

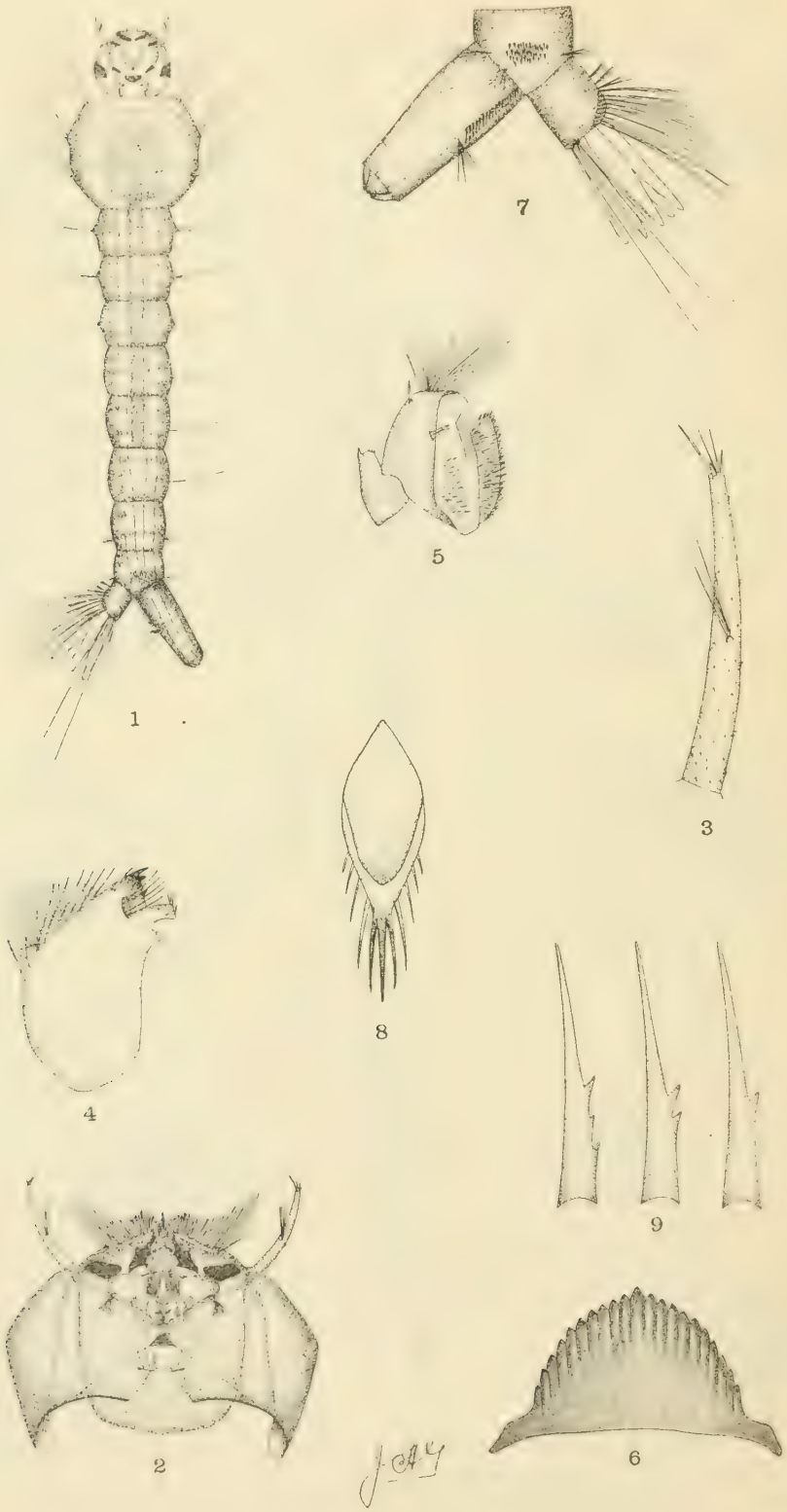


Fig. 11. Larva of the Brown Salt-Marsh Mosquito. (After John B. Smith).

1 larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal segments and siphon; 8, single scale from 8th segment; 9, siphonal spines (all much enlarged).

year (1904); but that is probably the southern limit of their dominance, and in ordinary seasons it does not extend so far. Just why they should be more plentiful on the northern marshes I do not know, nor what prevents their development along the southern shore."

Since these words were written investigations that throw light on this matter have been completed. It has been shown by Chidester[2] that *A. cantator* thrives in waters of comparatively low salinity (6 to 8 per cent) which prevails throughout the New Jersey coast in the spring and that *A. sollicitans* thrives in water of high salinity (10 to 15 per cent) which prevails during the latter part of summer. A further proof of this factor is found in the fact that the brackish marshes along the upper courses of our rivers breed *A. cantator* throughout the entire season.

It seems, therefore, reasonable to believe that the distribution of these two species in point of time is mainly dependent upon the salinity of the marsh waters in which they normally breed. High salinity appears to inhibit the hatching of the eggs and the development of *A. cantator* while it favors the development of *A. sollicitans*. Low salinity appears to inhibit the hatching of the eggs and the development of *A. sollicitans* while it favors the development of *A. cantator*.

It seems likely to the writer that the inhibition of egg hatching is probably the more important because an area which in spring gives off broods of *A. cantator*, as the salinity rises may give off a brood of *A. sollicitans*.

THE UNBANDED SALT-MARSH MOSQUITO

(*Culex salinarius* Coq.)

Recognition Marks

This species may be distinguished from *Culex pipiens* by its darker and more lanky appearance, but this difference becomes clearly distinguishable only when a long series of fresh specimens of each species is at hand. When the mosquito becomes worn, or is present in small numbers, it can be separated from *C. pipiens* only by a careful comparison such as outlined on page 24.

The larva is found in pools on the salt marsh or on adjacent upland. The wriggler is much like that of the house mosquito, differ-

[2]Chidester, F. E., 1916. The influence of salinity on the development of certain species of mosquito larvae and its bearing on the problem of the distribution of species. N. J. Agr. Exp. Sta. Bul. 299.

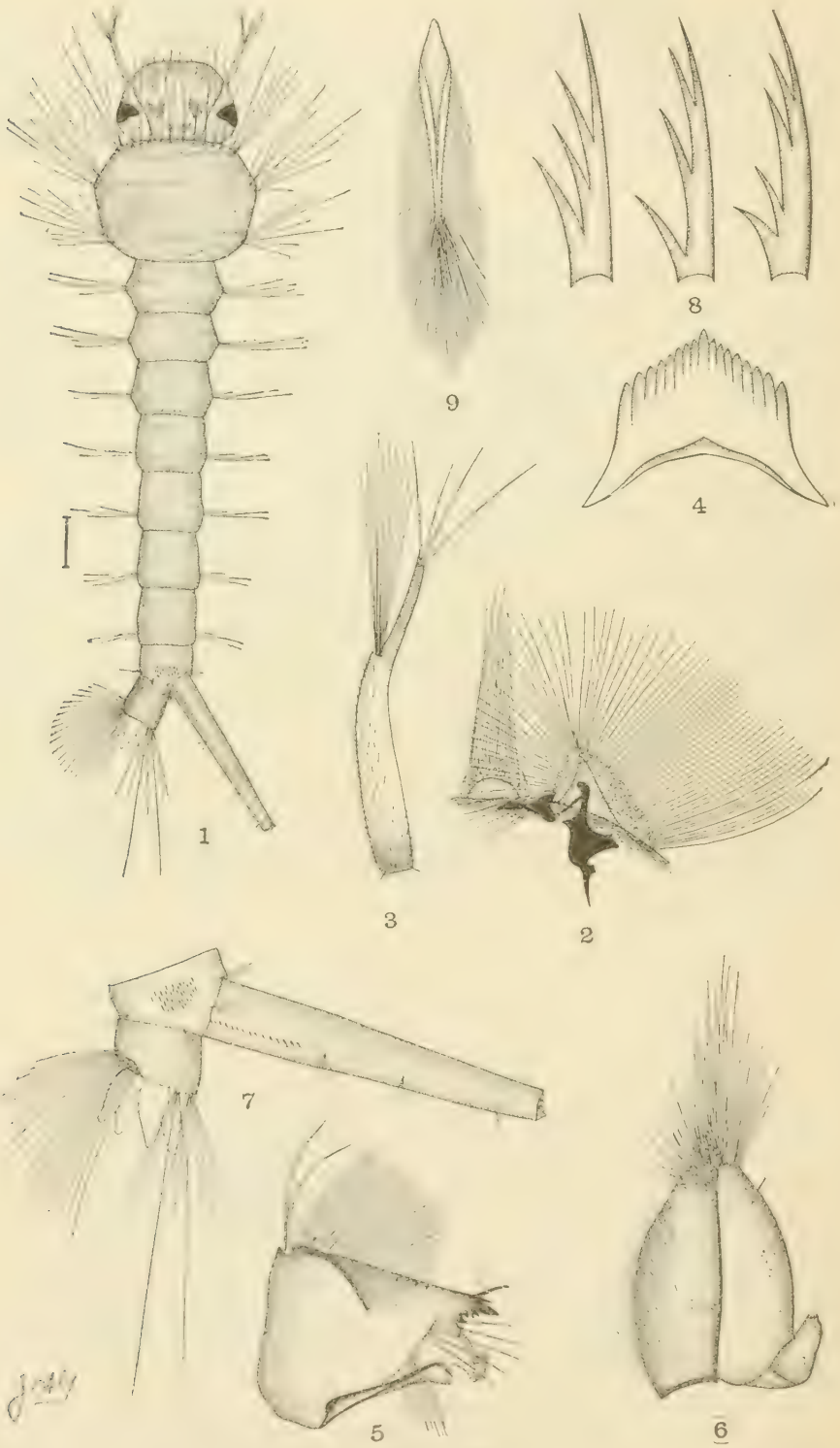


Fig. 12. Larva of the Unbanded Salt-Marsh Mosquito. (After John B. Smith).

1, larva; 2, mouth brush; 3, antenna; 4, mentum; 5, mandible; 6, palpus; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from the 8th adbominal segment (all much enlarged).

ing in having a longer breathing tube which tapers regularly from base to tip and is free from local swelling or inflation.

Importance

At the present time we have no reliable evidence to show that this species is of any great economic importance. It shows the same house-infesting tendency as *C. pipiens* and may, when the houses come within its range, prove very troublesome. Some years ago this species and *C. pipiens* bred in enormous numbers on certain of the sewage-charged salt marshes, and mosquitoes collected in the vicinity showed considerable numbers of the lanky dark form. It may eventually be proven that under these conditions *C. salinarius* plays almost as serious a role as *C. pipiens*.

Fig. 13. Pool-dotted salt-marsh breeding ground.

Life Habits

This mosquito, like *C. pipiens,* winters in the adult stage in protected places. Hibernating specimens have been found in buildings along the edges of the marsh. In April they desert their winter quarters, begin breeding and may continue until October. The eggs are laid on the surface of the water in a mass like those of the house mosquito (*C. pipiens* Linn.). The egg boats of this species are loosely formed and break up quickly. While the larvae appear everywhere on the marsh, they occur in decidedly greater numbers near the upland.

C. salinarius is most abundant on the Elizabeth, Newark and Hackensack marshes. During 1913 it bred most abundantly in the sewage-charged marshes in the same water with *C. pipiens*.

Importance of the Salt-Marsh Group

Figure 128 shows that before anything was done to prevent it more than one-half of the state's area was subject to the flight of the salt-marsh mosquitoes and fully three-fourths of the population suffered during the summer from their attacks.

Fig. 14. Breeding pool at close range.

It is believed that the salt-marsh mosquito forms a bar, and largely serves to prevent the natural flow of agricultural capital and labor from regions of high-priced land and distant markets to infested sections of the state where good soil is comparatively cheap and the best markets of the country are nearby.

In eight of the southern New Jersey counties, all of which border on navigable water, there are 631,000 acres of improved farm land with a valuation of about $56.00 an acre. Considering the quality of soil and proximity to markets this land should be worth $150.00 an

acre. In these same counties there are 600,000 acres not at present improved which are valued at not more than $20.00 an acre. This land, if improved to its capacity, as shown by areas such as lie about Hammonton and Vineland, should be worth $100.00 an acre.

In view of the fact that at many coastal seashore resort efforts have come to naught and proved a total loss through the presence of mosquitoes, it is fair to assume that the salt-marsh mosquito pest has proven a bar to that degree of development of the seashore resort industry which corresponds to the demands of the large urban population.

Fig. 15. Solid salt marsh where breeding occurs.

Along the 150 miles of seacoast from Keyport to Cape May, inclusive, there are 160,000 acres or more of possible home and hotel sites swept by ocean breezes and blessed with a delightful, clear, sunny, summer climate, which encourages bathing, sailing, and other outdoor seaside activities. Only 3300 acres of this area shows any attempt at development, and on a large part of this acreage nothing has been done except to lay out building lots. Nevertheless, in the towns and boroughs included, taxable values reach at present 262 millions of dollars. Continuous shore development occurs successfully only in regions naturally free from the salt-marsh mosquito pest, elsewhere successful development has taken place scatteringly and where the peculiar location renders a limited area largely free from mosquitoes.

It is believed that the presence of the salt-marsh mosquito has been a factor in retarding the development of the low-lying level areas

in the metropolitan district. In this area there are 28,000 acres lying in the Hackensack Valley and along Newark Bay, bordering Elizabeth, Newark, Jersey City and smaller cities and towns. These areas border or are penetrated by excellent waterways which already

Fig. 16. Sheet water breeding on a solid salt marsh.

have been or are capable of being deepened for ocean-going ships, and crossed by some of the principal railways of the country. They lie next door to the greatest seaport of the United States.

Before anything was done to prevent salt-marsh mosquito breeding, countless millions of these insects were produced during the summer in stagnant pools all over these marshes, and the main-

tenance of large forces of industrial workers on this area was greatly interfered with by the presence of these pests, which during large flights gave them no peace by day or by night.

Fig. 17. Diagram of salt-marsh mosquito conditions.

At the present time not more than 5 per cent of this area has been developed for industrial or any other purposes.

In the past it has been definitely recognized that the presence of the mosquitoes, which have bred on these lowlands, has so materially

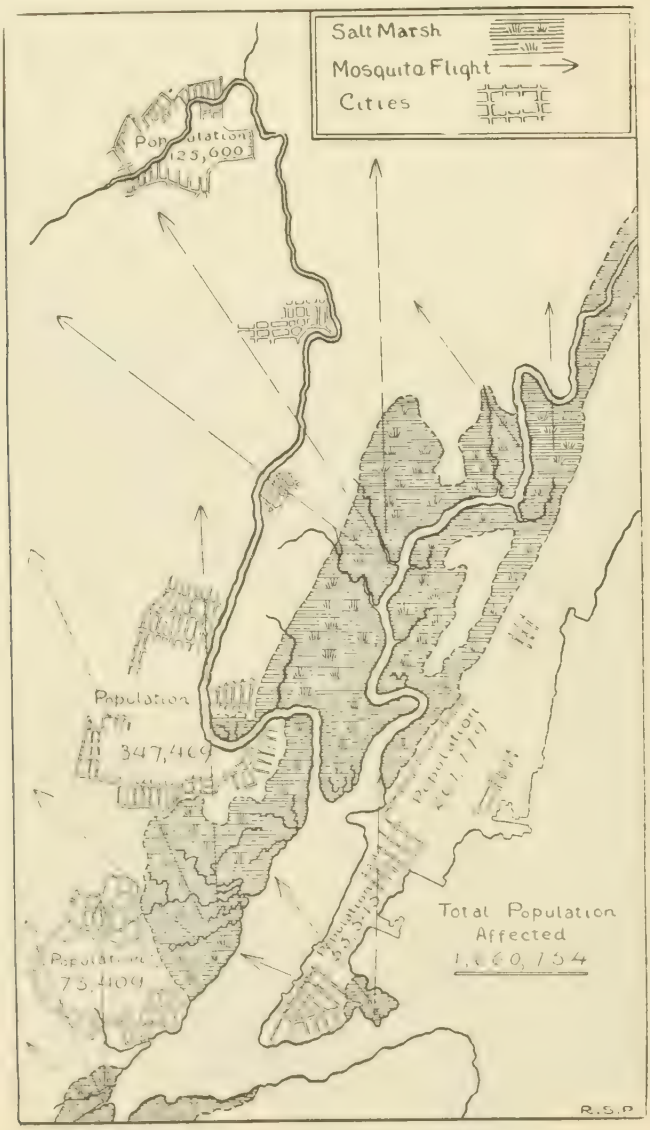


Fig. 18. How the salt-marsh mosquito operates.

interfered with the comfort of the million and a half people living on the adjacent upland that the development of suburban homes has been greatly retarded.

Thus it appears that the salt-marsh mosquito has materially interfered with the agricultural, seashore resort, industrial and urban development of New Jersey, and the following table will serve to

show graphically something of the development during the next 20-year period for which the suppression of the salt-marsh mosquito would open the way.

Agricultural—		
631,000 acres of unimproved farm lands in eight South Jersey counties.		
Present value	$56.00 an acre	
Value when properly worked	150.00 an acre	
Gain	94.00 an acre	$59,000,000.00
600,000 acres of unimproved land in the same counties.		
Present value	20.00 an acre	
Value when properly developed	100.00 an acre	
Gain	80.00 an acre	48,000,000.00
Seashore resort industry, very conservative estimate, (last 20 years has seen almost if not quite as much)		200,000,000.00
Industrial and urban development, also very conservative		200,000,000.00
Total		$507,000,000.00

Fig. 19. Effect of salt-marsh mosquito on real estate.

These estimates do not take into consideration the effect of this development on the value of home and city property in the same inland sections. Without doubt the creation of tremendously increased markets would result in great increases in the value of home and city property in parts of the state not directly affected by the salt-marsh mosquito.

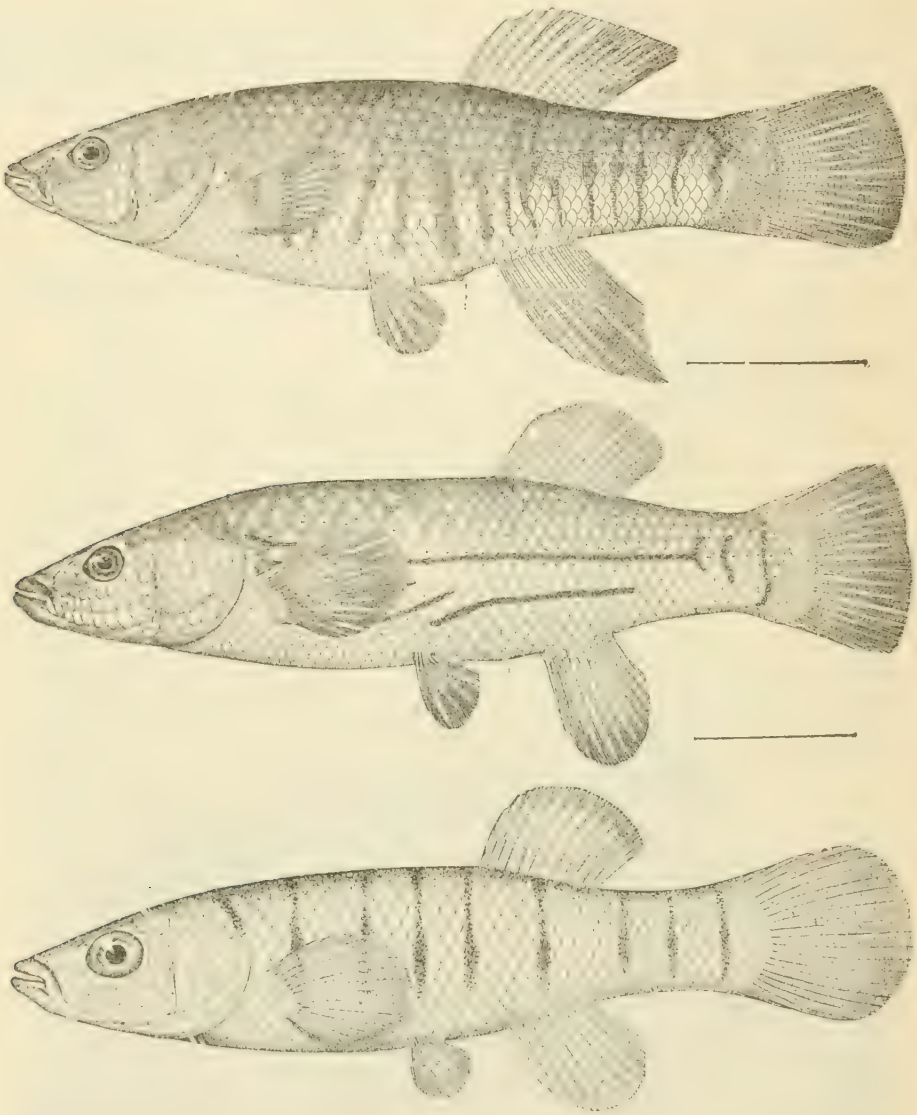


Fig. 20. The Striped Killifish; male above, female between and young below. (From Jordan and Evermann, U. S. Nat. Mus., Bul. 47).

Control of the Salt-Marsh Group

Natural

Fish as the natural enemies of the salt-marsh mosquito

The greatest natural enemies of the salt-marsh mosquitoes are certain small fish which make their homes in the creeks, ditches and ponds of the salt marsh. Five species of this type are recognized on the New Jersey marshes.

The striped killifish (*Fundulus majalis* Walbaum), which may be distinguished by the markings shown in figure 20, reaches a length of 6 to 8 inches. It occurs throughout the Jersey coast. It enters with the tide and goes out with it. It is useful, but less valuable than the following species for the purpose of mosquito control.

The common killifish, otherwise known as the "mud-fish," "mud-dabbler," "mummichog," and "salt-water minnow" (*Fundulus heteroclitus macrolepidatus* Walbaum), is perhaps more effective than any other fish as a salt-marsh mosquito larvae destroyer. The

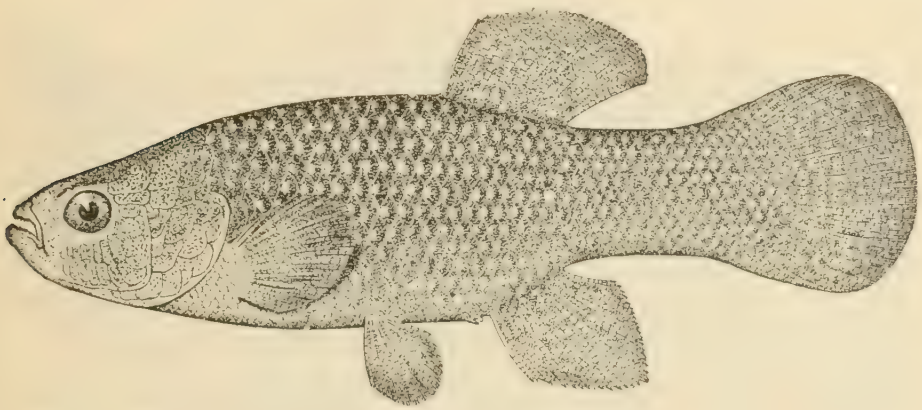


Fig. 21. The Common Killifish, male. (From Jordan and Evermann, U. S. Nat. Mus., Bul. 47).

females are nearly uniformly olivaceous but lighter below. The males are dark greenish, with many narrow, irregular, silvery bars on the sides, and the belly is yellowish or orange. The sides are more or less spotted with white or yellow. This species reaches a length of 4½ inches and occurs throughout the New Jersey salt marsh. Mr. Seal has the following to say about it: "This species is abundant everywhere to the extreme limits of tide water. They are equally at home in salt or fresh water, the clearest water or the muddiest pool or ditch. They are not even averse to filthy sewage water, collecting in vast numbers at the mouths of sewers at low tide. They will be found in the most insignificant and shallowest depressions on the flats or marshes, in ditches filled with reeds, spatterdocks or masses of submerged plants, and in muddy holes devoid of plants or other shelter. They will push through places where there is hardly enough water to cover them."[3]

[3]Smith, J. B., 1904, N. J. Agr. Exp. Sta., Report on Mosquitoes, p. 98.

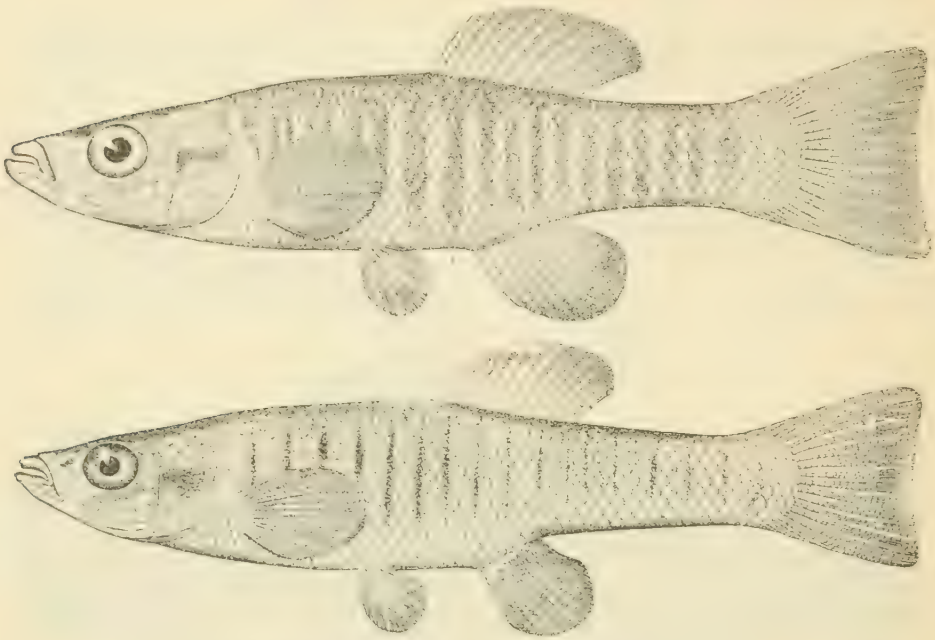


Fig. 22. The Fresh-water Killy; male above, female below. (From Jordan and Evermann, U. S. Nat. Mus., Bul. 47).

The fresh-water killy (*Fundulus diaphanus* Le Sueur) which reaches a length of about 5 inches, has the same range as the common killifish but shows a tendency to confine its movements to open channels and currents. The young mingle and move with the former but as they grow older separate more. This species differs from its allies in that it has a tail squarely cut off and not rounded. The females are olivaceous. The sides are traversed by 15 to 20 pearly white crossbands.

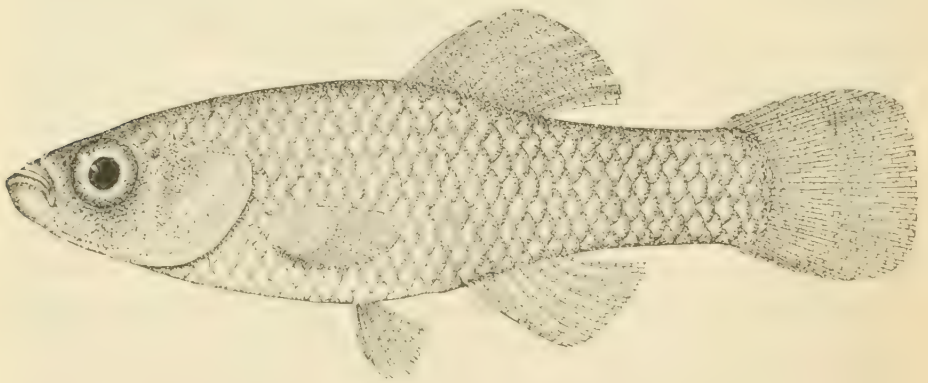


Fig. 23. The Rainwater Fish. (From Jordan and Evermann, U. S. Nat. Mus., Bul. 47).

The rainwater fish (*Lucania parvia* Baird) is a very small species, ranging from 1½ to 2 inches in length. The males are olive or pale brown, with bluish reflections; the edges of the scales are darker. The females have pale olive fins without black spots or edging. In life the body is almost transparent. This species appears to be confined to the South Jersey marshes. It is not an active fish nor is it a top feeder. It does not run over the marshes like the killies.

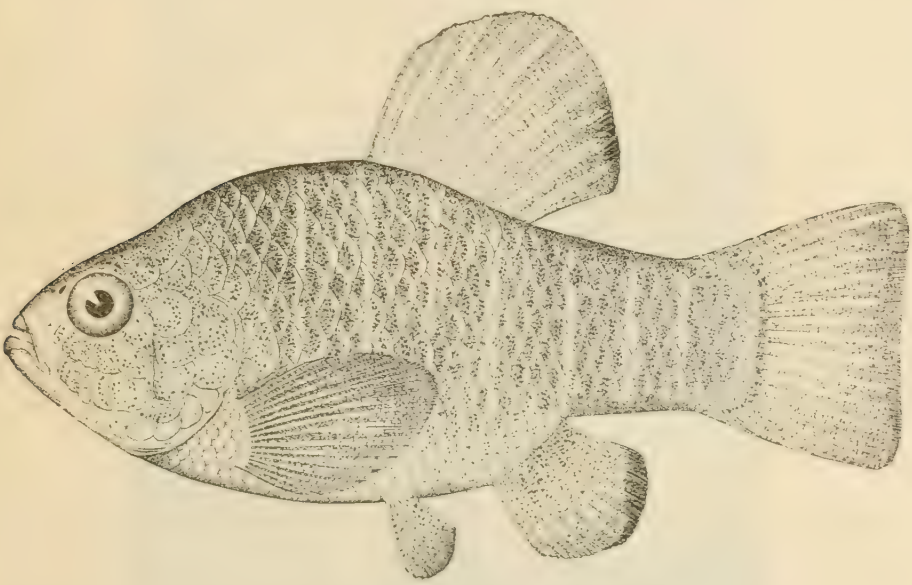


Fig. 24. The Sheepshead Minnow. (From Jordan and Evermann, U. S. Nat. Mus., Bul. 47).

The sheepshead minnow, otherwise known as the "variegated minnow" and "pussy minnow" (*Cyprinodon variegatus* Lacipede) occurs everywhere along the Jersey coast. Like the preceding species it collects in pools. Both this and the rainwater fish will live in ditches and pools foul with noxious gases. The general appearance of the sheepshead minnow is quite sufficient to separate it from the preceding species.

Speaking of all these species, Mr. Seal says: "Breeding, principally, in shallow pools left on the mud flats by the receding tides, the young appear in the spring in enormous numbers and remain there until they attain a considerable growth—1½ or 2 inches—when they begin to run in and out with the tide. As the tide covers the marshes and flats, these fishes move with it in an unbroken line like a heavy line in battle, feeding as they go. The chance of a mosquito larva es-

caping them is infinitesimal. Any waters to which these fishes have free access will be searched in vain for mosquito larvae."[4]

In the years 1914 and 1915 Dr. F. E. Chidester undertook and carried out an intensive study of the fish enemies of the salt-marsh

Fig. 25. Nature of breeding pool—Surface view.

mosquitoes. The investigations showed clearly that the common killy *(Fundulus heteroclitus)* is by far the most important fish enemy of the salt-marsh mosquito but that the fresh-water killy (*Fundulus diaphanous* Le Seur), the sheepshead minnow *(Cyprinodon variegatus* Lacipede), and the top minnow (*Gambusia affinis*) are commonly associated with it and play a strong secondary part.

Dr. Chidester's studies showed that this common killy migrated to

[4]Smith, J. B., 1904, N. J. Agr. Exp. Sta. Report on Mosquitoes, p. 93, 94.

the shallowest pools of the salt-marshes and traveled up streams into water of very low salinity, that when in land-locked pools it is able to maintain itself over winter by burying itself in the mud, but that when the way is open it will return to deep water and come to visit the marshes when the temperature reaches 45° F. In land-locked pools these fish burrow into the mud to a depth of from 6 to 8 inches, when the temperature of the water reached 45° F.

Fig. 26. Nature of breeding pool. What occurs in it.
1, eggs; 2, small larvae; 3, developed larvae; 4, pupae; 5, adult.

Dr. Chidester's work shows that the inland migration of the common killy begins as early as the latter part of March and that egg-charged females are found as early as April 19. In the early spring three types of this species enter and spread in the marshes: larger males and females, the latter of which will lay eggs in a week or two; medium-sized (one-half grown) which will not lay eggs for a month; and the small fish which are the products of the previous year and which will not lay eggs until toward the end of the season.

The eggs of the common killy fall to the muddy bottom and then undergo development. In about three weeks the eggs complete development and the young fry hatch.

From the time it is large enough the common killy feeds voraciously on mosquito wrigglers whenever it can get them. A single medium-sized fish will consume as many as 50 wrigglers a day.

Artificial

THE NATURE OF THE PROBLEM

Wherever the salt marsh or any portion thereof is covered by either tide or rain-water at summer temperature a brood of wrigglers (immature mosquitoes) hatches from the eggs with which the

marsh mud is stocked. In about one month in spring and only 8 days in midsummer these wrigglers, if the covering of water remains,

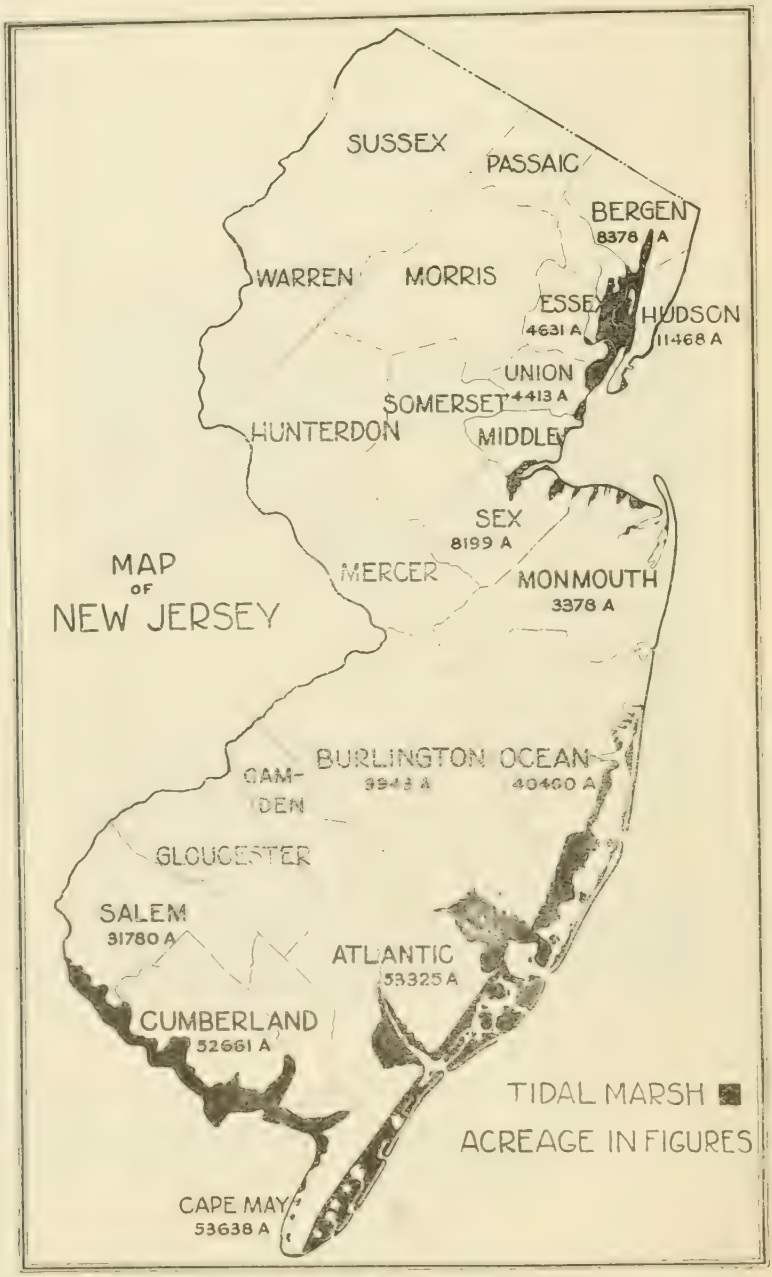


Fig. 27. Breeding salt marsh.

transform to myriads of adult mosquitoes, and a few days later distribute themselves on the wind, in some cases reaching points as much

as 40 miles from the place of breeding. Indeed, if the water persists only 7 days the mosquitoes will find enough moisture in the mud to complete their growth. Even if the water should drain off

Fig. 28. Salt-marsh areas of the state and the upland territory which was formerly covered by flights of salt-marsh mosquitoes.

several times before the last day, should it return in every case before the mud dries up, most of the brood will complete its development and escape.

Once each month during the warm season the tides run high. The first brood usually starts during late March or early April and reaches maturity in the last part of April or early May. Another comes out in June, another in July, another in August, and another in September. In South Jersey there may be another brood in October and still another small one in November.

While this regular succession of broods is the usual thing there are many exceptions. Sometimes, as a result of a long continued favoring wind, the tide will remain so high for ten days or two weeks, that the escape of water from drained but shut-in marsh is impossible and a brood of mosquitoes will mature and escape. Sometimes the weather will be so rainy and cloudy that the complete removal of the surface water is impossible and a brood may mature and escape. On the other hand, sometimes the tides will pass the full-moon period without rising high enough to cover the marshes and no brood will develop. Sometimes the weather will be so hot and dry that the surface water on the marshes will evaporate before the brood of mosquitoes can mature and none will escape. Sometimes the tides will run so low that areas which are usually swept by high tides with sufficient frequency to prevent breeding, may breed heavily.

Thus it appears that there are conditions during the mosquito season when almost no marsh will breed and still other conditions when almost any marsh will produce mosquitoes. In every case, however, study will show that to produce mosquitoes warm water free from killifish must lie on the marsh surface long enough for maturity to be reached or mosquitoes will not be produced.

Actual Work of Control

Treatment of the open salt marsh

Briefly stated, the control of the salt-marsh mosquito is a matter of so draining the marsh that none of the water which remains upon it will stagnate but all will rise and fall with the tide and be everywhere penetrated by large numbers of salt-marsh minnows commonly known as killifish.

Some parts of the salt marsh ordinarily do not breed mosquitoes and the work of eliminating breeding is reduced to the draining of certain parts. The principal factor in determining where on the marsh breeding shall occur when eggs exist under favorable conditions of temperature (55° F. and upward), moisture (enough to cover),

and salinity (15 per cent or less), is the killifish. Where they are present in considerable numbers no wrigglers are allowed to reach maturity—all are eaten. Apparently these efficient natural enemies are possessed of a desire to reach the edge of the marshes, for they penetrate every creek and ditch not closed by blockage and are to be seen at times making their way in shallow water among the grass stems.

Wherever the marsh-land is of such a nature that the high tides cover it at frequent intervals no breeding occurs, the writer believes, because the supply of "killies" is constantly renewed.

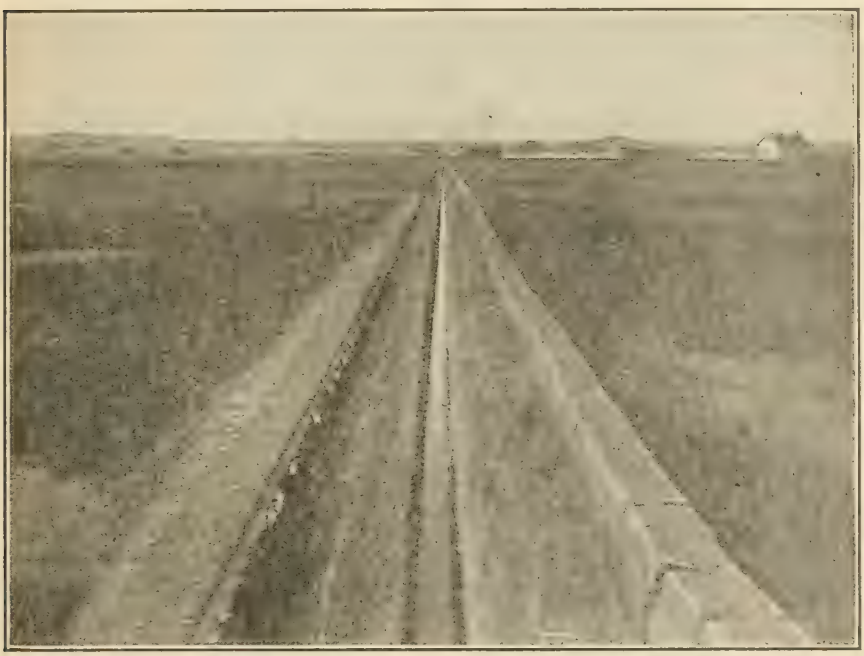


Fig. 29. The ditch 10 inches wide and 30 inches deep has been adopted as the best unit for open salt-marsh drainage.

High-lying or shut-in meadows over which the tide rarely sweeps are the breeders of salt-marsh mosquitoes. Even where an extra high tide has stocked the holes with killies the water dries up and the fish die; the rain-water fills the holes, the larvae hatch and mature, and a brood of mosquitoes gets on the wing.

The problem of eradicating the salt-marsh mosquitoes is thus seen to be one of determining just what parts of the marsh are breeders, intervals or that which remains in deep depressions will be kept constantly stocked with wriggler-eating fish.

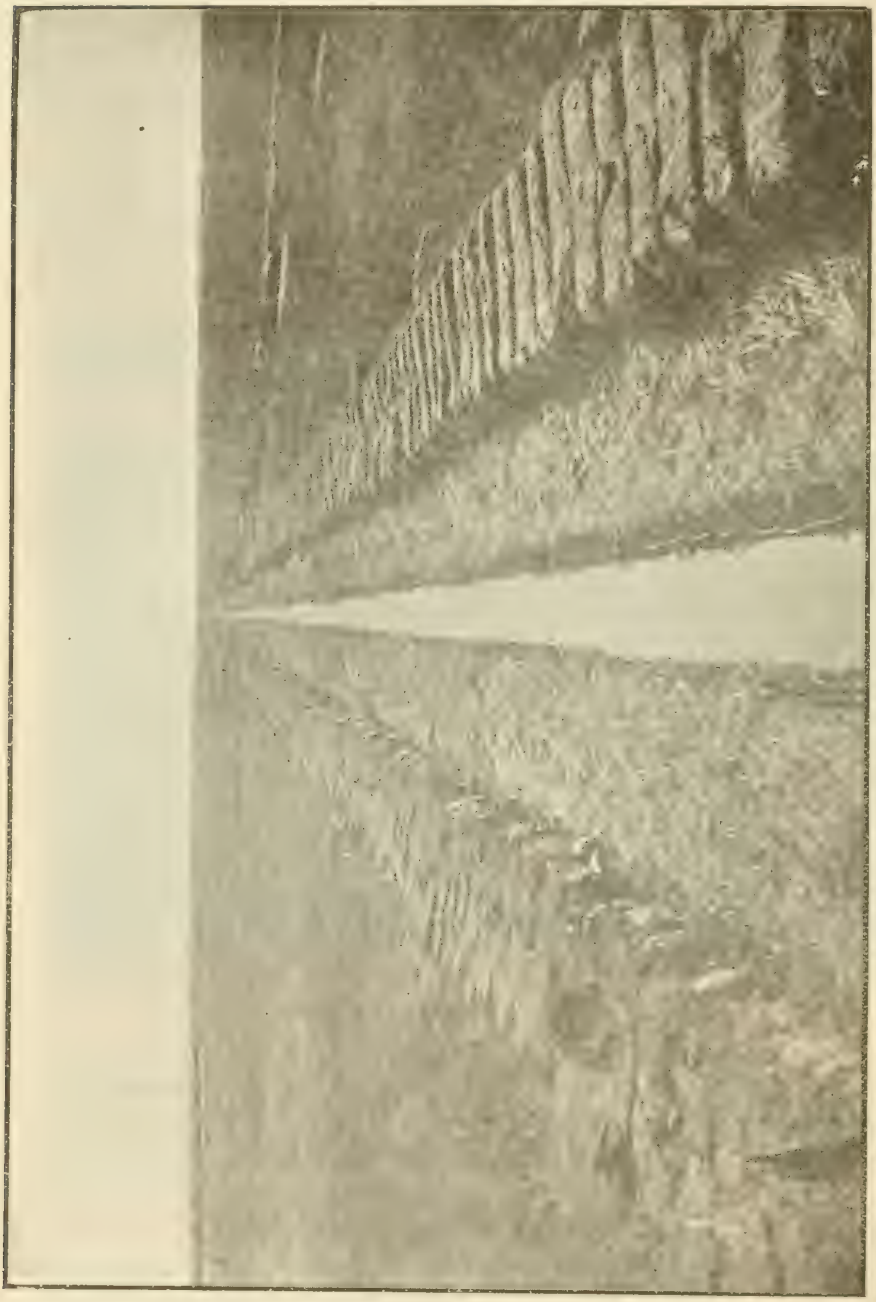


Fig. 30. Ditch 20 inches wide and 30 inches deep. When natural outlets cannot be had, hand ditches of multiple width are cut as outlets. (Courtesy of the Atlantic County Mosquito Extermination Commission).

More than 18 years ago, the late Dr. John B. Smith began to experiment for the purpose of determining the type of ditching that would accomplish this sort of drainage and could be put into the marsh and maintained with a reasonable expenditure. After many

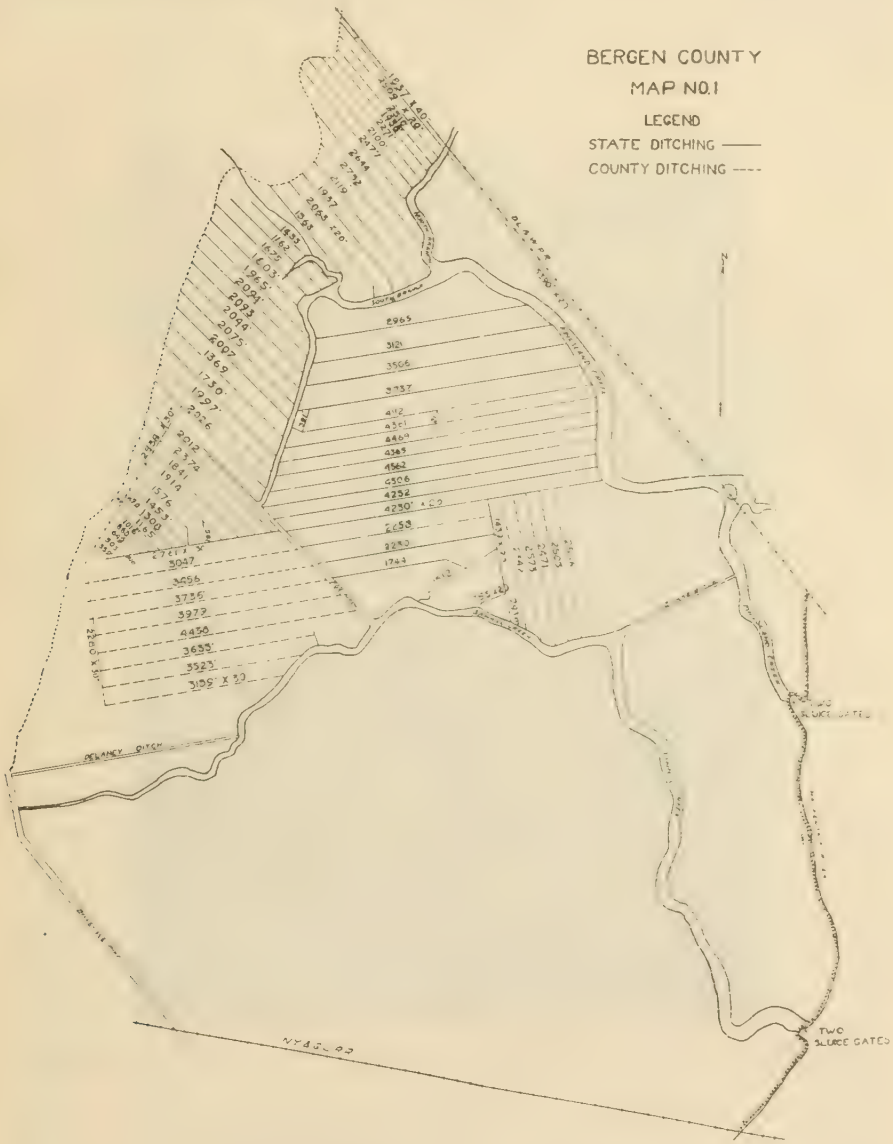


Fig. 31. Map of a ditching system.

trials, he settled upon a ditch 10 inches wide and 30 inches deep, with perpendicular, smooth sides, as the one most nearly fulfilling the requirements. This depth normally reaches the bottom of the sod and is maintained, except where a natural slope requires a

deeper cut to insure the free flow of the water. As the upland is approached, the sod and underlying muck become less than 30 inches deep and a sand or clay bottom appears. The ditches are allowed to become shallow as the sod gets thinner. Neither sand nor clay subsoil is cut into except as the drainage of a pool or area behind the barrier requires such action.

Fig. 32. Spur ditching; short ditches are run from the main to large salt holes.

In so far as the nature of the marshes will permit, these 10 by 30-inch ditches are opened into the natural creeks that meander through them. When such drainage is impossible, large main ditches, 30 inches deep by as great width as may be necessary, are cut as outlets.

In cutting the ditches it is best to remove the sod in pieces 10 inches wide, 30 inches long by 6 to 8 or more inches thick, because

these large pieces are heavy, not easily moved by the tide, and can be conveniently carted away by the landowners.

In every area ditched thus far, small shallow pools have been found which do not drain readily into the neighboring ditches and which are too small to merit drainage by means of a spur. Such holes are filled with sods from the ditches. In a couple of years the grass grows over the fill, obliterating the hole. After the sod filling has been thrown in, the surface of the rough pile is broken up and smoothed off.

The last few years have witnessed some very important changes in the methods employed in trenching the salt marsh for mosquito-control purposes.

It has been clearly shown during that period that no salt marsh is so well drained that it will at all times be free from mosquito breeding. There are times when, because of high tides, continued rain, and cloudy weather (during which the rate of evaporation is greatly lowered), the water derived from high tide or heavy rainfall or from both fails to be drawn off in time to prevent the maturing of the last remnant of the brood. Moreover, it may be said that the ditch mouths become plugged with sand or seaweed through the action of the waves and that by one means or another the ditches farther up in their courses become plugged with pieces of sod, accumulations of hay, and other rubbish.

It can be said, however, that during the past five years no case has come to the author's knowledge in which the 10 by 30-inch trenching of the ordinary high-lying salt marsh has failed to eliminate all but a small percentage of the brood which started.

The apparent inability of the ditching to afford complete control of breeding has demonstrated the maintenance of a patrol of the drained salt marshes throughout the mosquito-breeding season, as one of the measures necessary to successful mosquito-control work.

The greatest differences of opinion relative to the amount of trenching necessary to free an acre of breeding salt marsh from danger have existed, and to a considerable extent still exist. An attempt to discover the cause for this difference quickly reveals that each opinion is based on the particular area or areas of salt marsh with which the persons expressing them have had to deal.

Some marshes, because of a larger percentage of the area being filled with holes and depressions in which the high tide or rainwater is retained, require more extensive drainage than others. Furthermore, some marshes are protected from the tide by dikes

and the natural drainage water is removed by tide-sluices or even by pumps, and require on that account a larger amount of drainage the extra amount being necessary in cutting outlets for the primary system.

The estimated requirements range from 90 to 600 linear feet of 10 by 30-inch ditching, or its equivalent, per acre. As a matter of fact, only rarely is the former figure practicable and then under especially favorable conditions, and never on the New Jersey salt marsh has the latter figure been reached. It seems probable that between 200 and 300 feet is the real average. To this must be added an amount of hole filling and shallow spurring which will add about 10 per

Fig. 33. Small salt holes are filled with sod taken from the ditches.

cent to the acre cost. Fortunately, large portions of the salt marsh, particularly in the southern part of the state, are so low-lying and open to the tide as to be swept by every tide which is a little higher than the ordinary, and are on that account so free from breeding as to require no drainage. In a given area which includes a considerable amount of this kind of land, the required number of feet of drainage per acre will be materially reduced.

The plan of trenching has not undergone marked changes. By 1912 two general plans were in use—the first of which might be

called the parallel system, and the second, the pool-connecting system. The former was the one generally in use while the latter was thought to be adapted to particular conditions. In the parallel ditching scheme the territory to be drained was divided into districts on the basis of the possible outlet and each block of territory crossed by parallel ditches, lying sufficiently close to remove the surface water. Holes and depressions were spurred into these parallel ditches or filled with sod or other material. In the hole-connecting scheme ditches were run from one hole to another and finally into one or more outlets. It was held that such a plan was most practicable

Fig. 34. Types of tools used. Extra long-bladed garden spade and the ditch it cuts.

where the marshes were very full of salt holes. The experience of the last five years has clearly pointed out the superiority of the parallel ditching and the hole-connecting plan has been practically abandoned.

Since 1912 Eugene Winship, of the New York City Department of Health, has devised and caused to be installed a large amount of a still different system of salt-marsh drainage. It is known as the "Checker Board System" and consists essentially of two parallel systems one of which is superimposed on the other at approximately right angles to it. Mr. Winship claims superiority for the system on

Fig. 35. Types of tools used. The Skinner spade and the ditch it cuts.

Fig. 36. Types of tools used. The Manahan spade and the ditch it cuts. (After Hudson County Mosquito Extermination Commission).

the ground that with so many outlets it is practically impossible for the drainage of one area to become blocked and that the maintenance problem is therefore less difficult. This system has not found

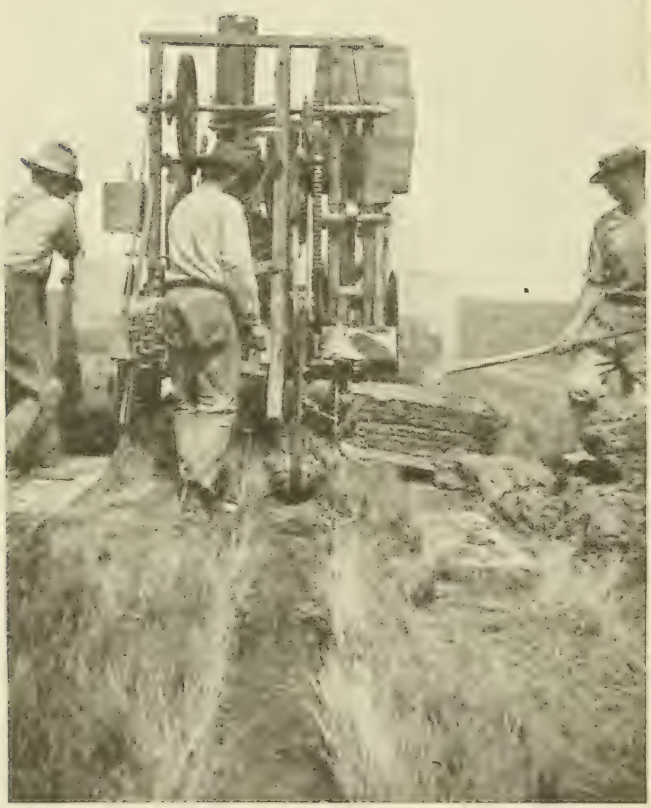


Fig. 37. Types of tools used. The Manahan power ditcher and the ditch it cuts.

favor in New Jersey for three reasons: (1) the cost of the system is much greater; (2) the meadows treated in this way are ruined for hay production; (3) the actual mosquito reduction is not materially greater.

Early in the salt-marsh trenching it was recognized that the type of outlet was of supreme importance and recent experience has served to confirm this notion. The greater the tide drop and the shorter the ditch the greater is its efficiency and its ability to keep clean. Every ditch should have a strong tidal outlet and no ditch depending on a single outlet should be over ¼ mile long.

The machinery used in cutting ditches has undergone some important changes. The hand tools have made little if any advance.

Fig. 38. Types of tools used. The Eaton spades.

The Manahan and the Skinner types of spades are still the prevalent tools and are so covered with patents that the trenching of the marsh by anyone not possessing the right to use these tools is both difficult and expensive. Recently Harold I. Eaton invented a practicable sort of hand spade but as a patent has been placed upon it the general public does not seem to be in a way to benefit by it materially.

A power machine has been invented by Mr. Eaton which unquestionably trenches the marsh with such ease and speed as to make a notable reduction in the cost of ditching. Essentially, the machine consists of a gasoline power plant placed on a pair of 12-foot long, 12-thick planks that are set within 5 feet of each other and strongly

bound together with cross ties. The front and rear ends of the machine each bear a revolving drum; upon the front a 250-foot ½-inch and upon the rear a 500-foot ¾-inch steel cable is wound. When the power plant must be moved forward or away in another direction and thrown into the sod, the power is then applied to the drum and the plant is drawn up to the anchor.

The plow or trencher consists of two 12-foot long, 10-inch wide and 2-inch thick planks set parallel and 10 inches apart. Suspended between these planks are two cutters. The point of the forward one is 15 inches below the under-sides of the planks and the point of the second 30 inches below. As the plow is pulled forward each cutter shears out and elevates a piece of sod 10 inches wide and 15 inches thick which it deposits as a long ribbon on either side of the ditch. The plow is attached to the power plant by a 500-foot steel rope which is wound up on the rear drum, while the power plant is standing anchored ahead.

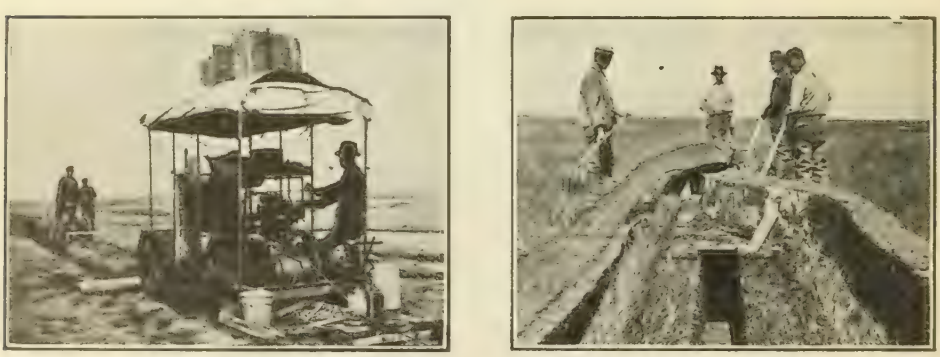


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Fig. 39. Eaton ditcher. (Photos by Atlantic County Mosquito Extermination Commission. (A) Near and front view of power plant with plow in distance; (B) Near and rear view of the plow showing the ditch and way the sods are disposed of. For ditch cut by the Eaton ditcher see figure 29.

With five men and a machine of this sort, which before the war could be had for $1750, it is possible to cut an average of 3000 feet of trenching a day, and in some cases more.

Before the war competition and the invention of this machine had cut the cost of ditching from 2½ cents a linear foot in 1912 to less than 1½ cents, and seemed bound to bring it lower yet, but the increased cost of labor has operated to keep the price up. The operation and upkeep cost of ditching with this machine, as has been shown by cutting hundreds of thousands of feet, under normal labor conditions, does not exceed a cent a linear foot.

Still more recently Mr. Fred A. Reiley, Superintendent of the Atlantic County Mosquito Extermination Commission, has invented an improved type of ditching plow. This plow cuts a ditch 10 inches wide and 30 inches deep, and is so arranged that it will enter the marsh without any preliminary digging and can be drawn out of the marsh, when the end of the ditch has been reached, by the use of power. This ditching plow looks much like the one invented by Mr. Eaton, but has the additional features of entering and of removal as specified. Mr. Reiley also has devised an entirely different and a much more efficient power plant. He makes use of a Fordson tractor, the wheels of which are fitted with wide extension rims, a drum is installed on the rear of this tractor and a cable of various length is employed for pulling the plow. After the plow has been drawn up to the tractor the tractor rapidly moves ahead to the new point, the anchors are drawn in, the power of the motor is thrown on to the drum and the cable is wound by drawing the plow up to the advanced point.

The efficiency of this new machine is such that as much as 10,000 feet a day can be cut under favorable conditions.

Treatment of the enclosed salt marsh

In some instances the drainage established by nature has been so interfered with by the activity of man in the building of railroads, roadways, dikes and banks, that reopening sufficiently wide outlets has become impracticable. Furthermore, this shutting in has in some cases so interfered with the vegetation that it has died and the marsh surface lowered in extreme cases as much as 3.5 feet. To make a bad matter worse, at many points the raw sewage from large populations has been emptied into these artificially formed basins.

The solution of the problem thus created involves the shutting out of the sea and the removal of such water as occurs behind the barrier either by gravity through sluices or by lifting out with pumps. A considerable fund of experience is now available for the treatment of shut-in marshes that have and have not shrunken. In the neighborhood of 6000 acres have been thus more or less completely treated for mosquito control. In giving an account of the methods employed in solving the problems involved it seems advisable to treat first the enclosed, non-shrunken, free-from-sewage areas, then the enclosed shrunken marshes and finally the enclosed shrunken and sewage polluted basins.

The enclosed, non-shrunken and sewage-free salt marsh. The problem on the first type (enclosed, non-shrunken and sew-

age-free marsh) is relatively simple because gravity furnishes all the power necessary to move the water.

Of course the first step in the drainage of the enclosed area is the installation of internal drainage of the type used on the open marshes. Whether dikes are necessary in such an area depends on the height of the meadows adjacent to the tide. When the natural land is well above mean high tide, which is usually indicated by the presence of prolific growth of salt grass (and the presence of a row or rows of debris brought in by the high tides) there is good reason to believe that in most seasons a dike would prove a useless expense. In such cases it is merely necessary to install sluices and tide-gates in the principal outlets and to block up the others, connecting them with the principal ones. Credit for the discovery and first utilization of this plan for mosquito control must be given to John Dobbins, of Newark.

When the land bordering the tidal water is low, which is usually indicated by the presence of coarse grasses and the absence of lines or rows of debris, or when the agency concerned wishes to provide against extreme tides, that portion of the area adjacent to tidal waters must be protected by a low dike and the water inside outletted by sluices and tide-gates.

The questions of dike, sluice and tide-gate construction for agricultural purposes have received a considerable amount of attention and the facts have been pretty well covered in Bulletin 240, of the Office of Experiment Stations, U. S. Department of Agriculture, Washington, D. C., and reports of the State Geologist of New Jersey. The utilization of this construction for mosquito control is comparatively recent but already it has been modified better to serve the purpose.

The height of the dike is made to depend upon the height of the tide it is expected to keep out. In one case the dike was built to an elevation of 7 feet above mean low tide, which was ½ foot higher than the previously recorded highest tide for the season of 1914. The intention was to build it high enough to keep out all but the very highest of high tides, the theory being that these extraordinary high tides come so rarely and at such times of the year that fencing them out is unnecessary.

The dikes as they were built stood 3 feet above the meadow surface, were 2 feet wide at the top and 6 feet wide at the bottom. Anticipating a shrinkage of about 25 per cent, the crest was made about 1 foot higher than the elevation called for.

A

B

C

D

Fig. 40. Dike construction. A. Cutting the preliminary trench; B. Tamping in the mud core; C. Gang at work on dike construction; D. Completed dike as it looked during the following summer. (Photos by Union County Mosquito Extermination Commission).

When the construction of the dike began, a trench 10 inches wide by 20 inches deep was cut along the line to be occupied by the structure, and the sods taken out utilized in making the dike. A row of sods composed of pieces approximately 10 inches wide, 12 inches high and 26 inches long was laid in each side of this trench with the grassy ends out, enclosing a space 20 inches wide. Mud was then tamped into the trench until its surface was flush with the upper surface of the sod layer. Then another layer of sod composed of pieces 10 inches wide by 12 inches high by 24 inches long was placed on top of each of the other two layers. Again the grassy ends were out but the ends of the upper layer were 6 inches nearer the dike center than were the ends of the lower layer. The central cavity thus formed was tamped full of mud. Then a third layer of sod was

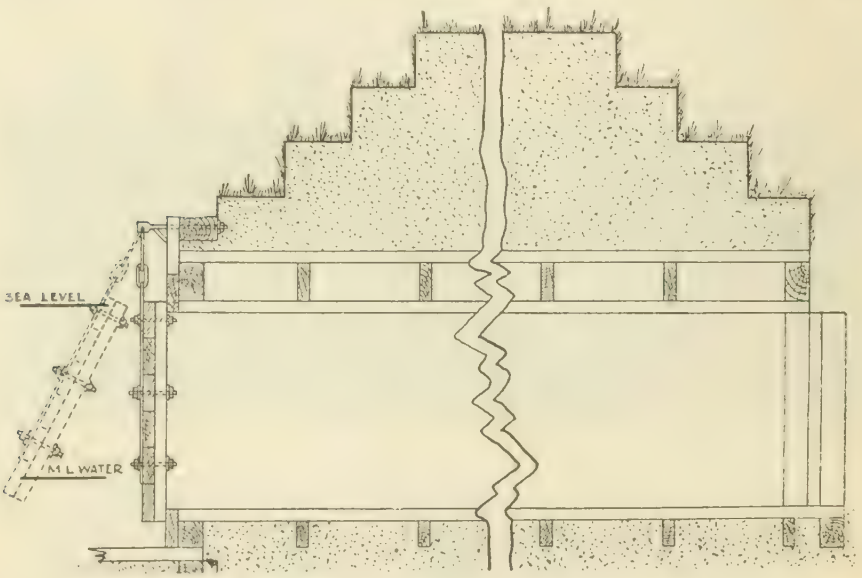


Fig. 41. Tide-gate construction. (Courtesy of the Essex County Mosquito Extermination Commission).

placed on the second in a similar fashion with a similar approach to the center. The space formed between the two parts of the layers was tamped full of mud. In some cases the dike thus constructed was covered with a layer of sod while in other cases the crest was simply rounded up with mud.

The sod and the mud for making the dike came from the preliminary trench and from a supply trench which was dug inside the protected area about 8 feet from the base of the dike. In some cases a supply trench was dug on each side of the dike. In every case the supply trench was of uniform width, did not exceed 3 feet in depth and was properly connected with adequate outlets.

During the summer of 1915 the grass in the sods grew vigorously and transformed the dike into a wall of green. The sods used in capping the dike dried out and separated until they looked like the battlements on a wall, and the layer became useless as a means of keeping water out. The mud cap settled down and formed a continuous solid cap serving much better the purpose for which it was intended than did the sod layer.

Some dikes have been constructed entirely with mud but always in places where sod was not available. In such instances the mud has been scooped from a trench back of the dike (forming a ditch

Fig. 42. Tide-gate completed. (Courtesy of the Union County Mosquito Extermination Commission).

paralleling the work and giving useful drainage), and piled up until a dike of requisite height with due allowance for shrinkage had been built, which was 2 feet wide at the top and as broad at the base as was demanded by the normal angle of repose. This type of dike does not withstand the weather or the water as well as the sod type but is efficient if carefully looked after.

At points where streams or larger ditches cross the dikes sluice-boxes and tide-gates were introduced. The largest sluice-box used measured inside 3 feet high, 6 feet wide and 24 feet long. It was made of 2-inch lumber nailed to outside ribs at a distance of 18 inches apart. The box was set on 2 rows of 2-inch sheet piling and then covered with soil. A large heavy wooden door was suspended over the down-stream end of the box to serve as a tide-gate. The following specifications have been used in the construc-

tion of sluices employed as an outlet for a large creek which, at the point where the gates were introduced, was 75 to 80 feet wide.

1. All sluices shall have an inside measurement of 6 by 3 feet and shall be built of 3-inch tongued and grooved long-leaf pine, free from knots or serious blemish; they shall not be shorter than 15½ feet and shall extend from the outside of the dike—facing back under the dike. These boxes shall be stiffened with 4 by 5-inch ribs bolted at each corner with a one-half-inch bolt properly washered and drawn up with a satisfactory nut. These ribs shall be placed around the outside of the box fitting it closely at distances of 18 inches apart. The first and last shall be made flush with the ends of the box. The planking shall be firmly spiked to these ribs with 6-inch galvanized spikes. The top of the box shall be covered with 2-inch long-leaf pine spiked on the top of the ribs.

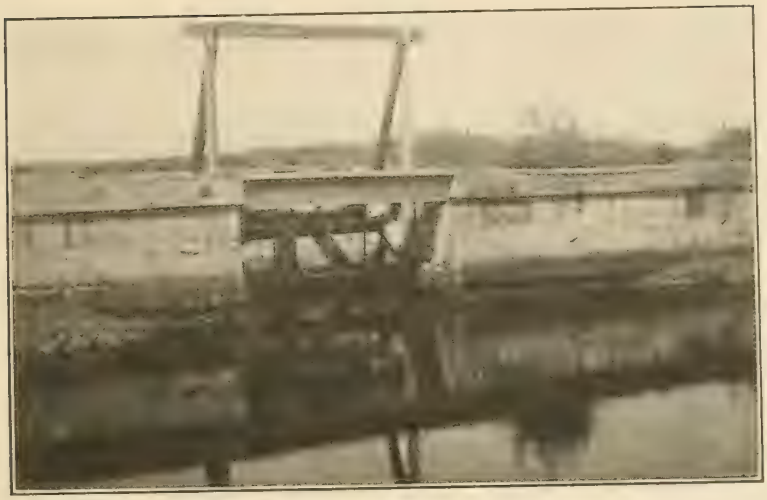
2. The dike shall be faced on the river side with plank piling for 120 feet at the mouth of Kingsland Creek. This facing shall consist of 3-inch long-leaf pine planking, free from knots and serious blemish, not less than 14 feet long driven in until the top shall be 1 foot below the level given for the top of the dike. If the tops of the piles are splintered, split or broomed by driving, they shall be cut off below the lowest point of injury. In any case the cut-off ends shall not be such as to make the length of pile less than that provided. The top of the piling shall be even and bound together by running a 3 by 8-inch stringer along the outside and inside surface.

Each pile shall be bound to this stringer by a ½-inch bolt which shall be furnished with large washers and a suitable nut. The opening for the sluice-boxes shall be made closely to fit the box. The cut ends of the piling above the box shall be bound together by 3 by 8-inch stringers which shall extend one on the inside and one on the outside from a point 2 feet beyond the opposite edge of the opening. These stringers shall be set flush with the cut ends of the piling and each pile which they cover shall be bound to them by a ½-inch bolt properly washered and fitted with a nut. The cut ends of the piling below shall be bound together in the fashion above described.

3. All sluice-boxes shall be laid on two extra rows of sheet piling composed of 3-inch long-leaf pine closely set together. The planking shall be 10 feet long and driven in until the top shall be 9 inches below mean low tide. The above provision regarding injury due to driving and its correction shall be observed here. Each row of this sheet piling shall be bound together at the top in a fashion similar to that provided for the dike facing, and the piling at the sides of the boxes shall extend up through the stringers 1 foot and the rectangle thus formed shall be made closely to fit the boxes.

4. At the sluice-boxes the inner side of the dike shall be protected by sheet piling wing-walls made of 2-inch long-leaf pine without serious blemish, 14 feet in length driven in until the top is 1 foot below the level of the dike. The above provision regarding injury due to driving and its correction shall be observed here. They shall be bound together at the top in the same fashion as the dike facing, and shall extend 6 feet each side of the sluice-boxes.

5. The river side of each sluice-box shall be furnished with a 7 by 4-foot gate made of tongued-and-grooved white pine. It shall be composed of two layers, the inside one being made of 3-inch 7-foot-long planking and the outside one of 2-inch 4-foot-long planking laid at right angles to one another



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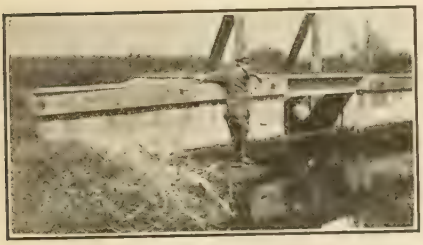

B

C

D

E

Fig. 43. Relative level of water on the protected area as compared with the tide. A. Sluice and gate in Maple Island Creek. B. Same just before the sluice begins to discharge. C. Same showing medium tide level, see the level of Mr. Walden's boot soles. D. Same showing extreme high-tide level, see level of Mr. Walden's boot soles. E. Same showing relative level of water inside and outside the dikes under extreme high-tide conditions, (1) shows Mr. Walden standing at water level inside the dike and (2) shows the same man standing at the level reached by the water outside the dike under extreme high tide.

and firmly spiked together. The gate shall be hung in front of the opening with a suitable link hinge so that it will readily open with the falling tide and readily close with the rising tide.

Lighter sluice-gates have been employed but no larger or heavier ones. If the capacity of more than one was needed duplicates have been installed. This plan has been followed because gates larger than this have elsewhere proven difficult to keep in working order.

Recently, Mr. Brooks has devised another type of sluice-way and tide-gate, which the writer has since found to have been antedated. In this case no box is constructed. Heavily timbered bulkheads are built on both sides of the stream approximately 6 feet apart. To render their relation to each other constant they are bound together by heavy cross timbers. (A floor is laid from one end of the opening to the other.) At a point half-way between the two ends, a pair of heavy 6 by 6-inch well braced timbers are set down in such a fashion as to form the support and resting place for the tide-gate. Of course, the joints between each of the upright posts and bulkhead against which it stands and between the lower cross-timbers and the bottom are made tight.

The tide-gate is suspended from a cross-timber located well above extreme high tide, and hangs against the upright posts. At each end the bulkheads are fitted with slots in which planking can be dropped to form a coffer dam. The water between the two bulkheads has merely to be pumped out, when these dams are in place, to expose the gate for repairs and the sluiceway for cleaning. The top of the sluiceway thus formed is left open. Mr. Brooks holds that the greater ease with which this type of gate can be kept in good working order is sufficient to warrant its adoption.

Experience in 1918 has clearly demonstrated that for all types of tide-gates the piling must be driven well into the solid substratum or the structure is likely to go out. Any movement whatever of the sheet piling seems likely seriously to damage the latter type of gate described.

The problem of preparing a proper dike, sluice-boxes, and tide-gates for draining a given area is an engineering one. Suffice it to say that the trenching, diking, sluicing and tide-gating must be so planned as to keep out all but the most extraordinary high tides and to free the surface from water within 5 days after a heavy rainfall.

The last step in the initial treatment of this type of marsh to prevent maturing of mosquitoes is the arrangement of the drainage system and the manipulation of the tide-gates in such a fashion that

tide-water with its supply of killifish can be brought into the area and caused to circulate (without overflowing the ditches) throughout the system and again escape from the area. Experience has clearly shown that failure to provide for this circulation is followed by breeding in stagnant water in the ditches requiring the extensive use of oil which can not usually be made sufficiently complete to prevent the emergence of all of the mosquitoes. The circulatory feature of the drainage system on the enclosed, non-shrunken, non-

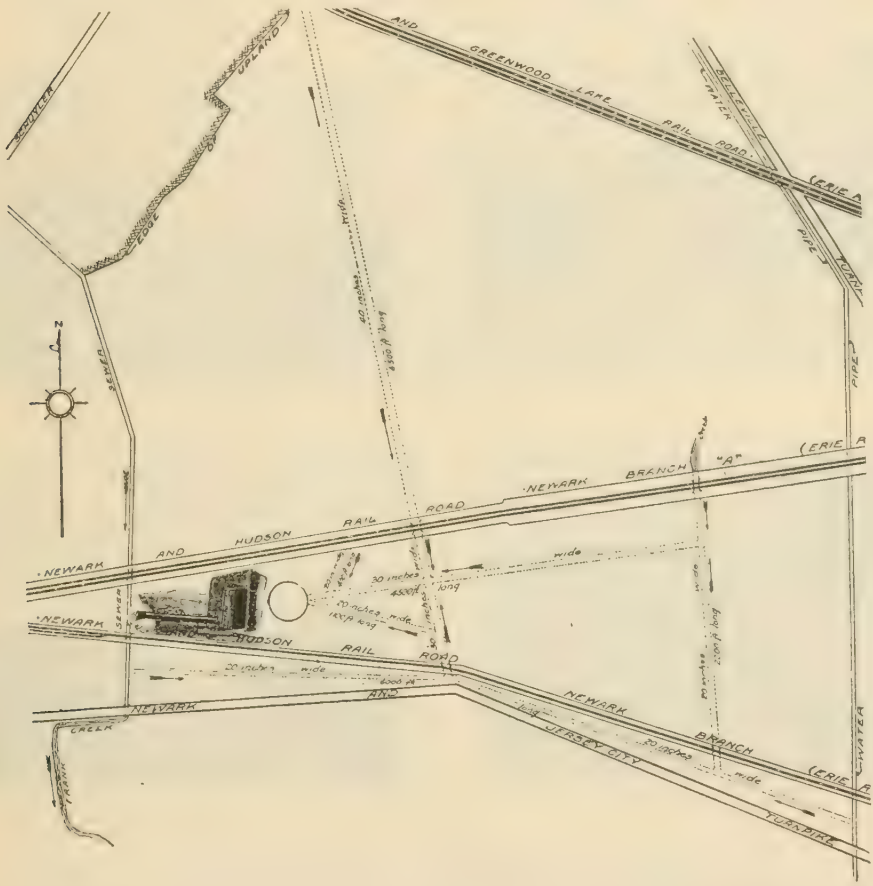

Fig. 44. Drainage system on an enclosed, sunken and sewage-charged marsh.

polluted marsh is just now in process of being worked out. As the matter now stands it seems best to bring the water in through a large channel and to provide for its passage along the foot of the upland and its escape through the narrow trenches into the main outlets. Such a scheme is now in partial operation on the North Elizabeth meadow.

At this point the danger which marsh enclosure involves should

be emphasized. If the brackish water is withdrawn from the marshes and kept off too continuously the salt grasses will die, their deep penetrating roots will rot, the particles of soil will come closer together and the surface of the marsh will lower to such an extent that removal of water by pumping may become necessary. If the gates are kept completely open from the first of November until the end of the following March, especially if the circulatory system above described is inaugurated, the strength of the salt-grass sod is not likely to be impaired.

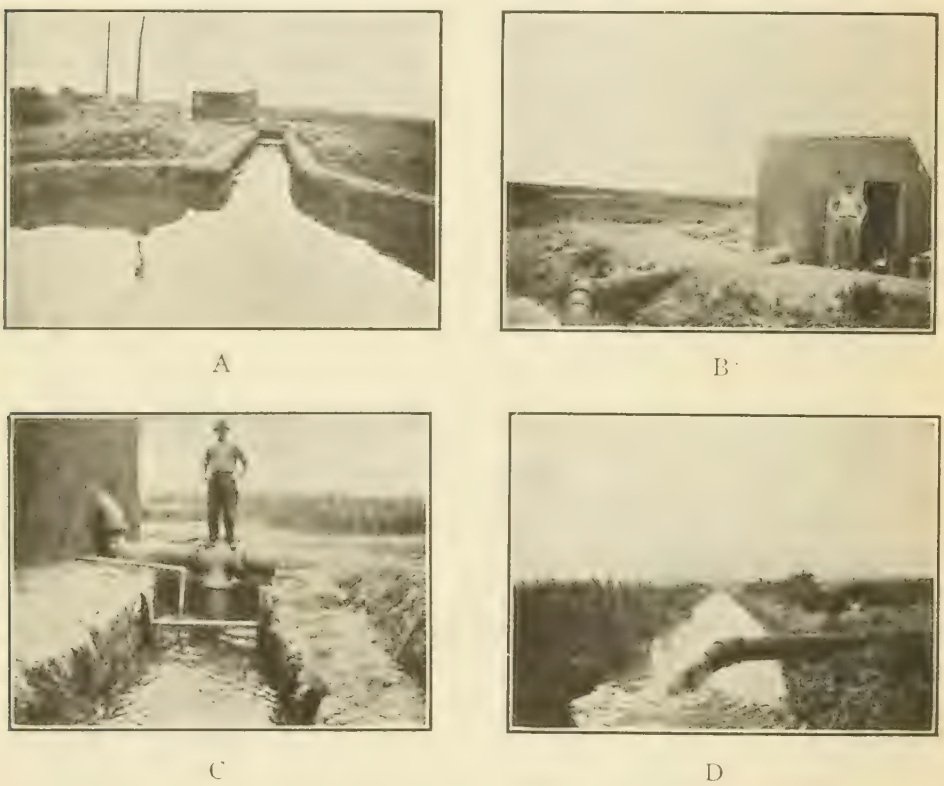

Fig. 45. Twelve-inch centrifugal pump, which was installed to drain an area of marsh slightly below sea level. (Photos by Hudson County Mosquito Extermination Commission).

The enclosed, shrunken but non-polluted salt marsh. The second type of enclosed marsh (enclosed, shrunken but non-polluted basins) must either be opened to the tides and thus covered with tidal water and shoals of killifish or the water removed by sluices and tide-gates supplemented by pumps. Numerous examples of this type of enclosed marsh exist along the coast. The examples

are usually where the marsh, which has been diked, sluiced and cultivated, has been allowed to fall into neglect. The dikes have been breached and the sluices have rotted away, and ordinary tide covers the land regularly. In such places no breeding occurs except along the edges of the highland where the water is screened away from the fish.

When dikes have been erected to keep the sea out, sluices and tide-gates will be found useful to remove cheaply the surplus water lowering the water level to about 1 foot above mean low tide. Pumps must be installed to remove the balance because the surface is likely to be covered more or less with pools after the utmost low water reached by gravity has been attained.

Pumps of various types have been used and thus far the low-head centrifugal kind has been most satisfactory. One 12-inch pump of this type when contributory ditching has been so arranged as to permit it to work at its limit of efficiency seems quite sufficient to remove the surplus water from 1000 acres. Such a pump cannot do this, however, unless the water is removed and a reservoir of surface soil from 8 to 12 inches thick has been dried out before the mosquito season starts, for with water at the marsh surface an extra heavy rainfall would so fill up the marsh that mosquitoes would probably escape before the water could be drawn off. This would be especially likely to occur when the rainy period is followed by cloudy weather, reducing evaporation to the minimum.

In dealing with marshes of this type either provision must be made to bring in brackish water with its supply of killifish, to be circulated through the ditches, or the ditches must be pumped dry and kept so. The former alternative is probably the better plan, because the adoption of the latter is likely to be followed by the appearance of growth in the bottom of the drains creating blockages and eventually breeding places.

The enclosed, shrunken and polluted salt marsh. The third type of enclosed marsh (enclosed, shrunken and polluted) must be enclosed to keep the sea out and must be pumped dry and kept pumped dry throughout the mosquito-breeding season. Much greater pumping capacity will be required than in the second type because not only rainfall but constant sewage discharge must be removed. The size of the pump depends not only on the acreage to be cared for but upon the volume of sewage being discharged.

The introduction of brackish water into such a marsh is usually

worse than useless because the killifish cannot live in the sewage and an increased volume of water is to be removed.

The House-Mosquito Group

The house mosquito (*Cupex pipiens* Linn.) is so predominant in this group that there seems little reason to mention any other species except possibly the white dotted mosquito (*Culex restuans* Theob.).

The House Mosquito

(*Culex pipiens*)

Recognition Marks

Dr. Smith[5] characterizes the house mosquito as follows: "It is of medium size, deep yellowish to dark brown color, the legs and beak are not banded, and the abdomen has a narrow whitish band at the base of each segment. It is rather a slight species and not especially hairy—having, indeed, a lean and hungry look."

The larva is found in almost all sorts of stagnant fresh-water pools and in water on the salt-marsh when it has become sewage-soaked. Pools charged with fish or well exposed to the rippling effect of the wind rarely show any breeding. The house-mosquito larva is pretty well characterized to the naked eye by its very long breathing tube which is at least four times as long as broad. There are other species sometimes found in house-mosquito pools that so resemble it as to render the use of the microscope necessary. With this instrument the house-mosquito larva can be separated from others by the following points: (1) the sides of the breathing tube are a little swollen out or inflated; (2) the antennae arise from the sides of the anterior part of the head and have the hair tufts beyond the point midway from base to tip; (3) the scales on each side of the eighth abdominal segment are twenty or more in number, are separate and form a large patch; (4) there are 4 tracheal gills.

Importance

None of the species of mosquitoes in New Jersey, with the exception of the two migrating salt-marsh species (*A. sollicitans and A. cantator*), can compare with the house mosquito in injurious power. It is everywhere about human habitations. It breeds in large numbers wherever water stands long enough. It penetrates our screens and attacks us at night as we try to sleep.

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[5]Smith, J. B., 1904, N. J. Agr. Exp. Sta., Report on Mosquitoes, p. 10-11.

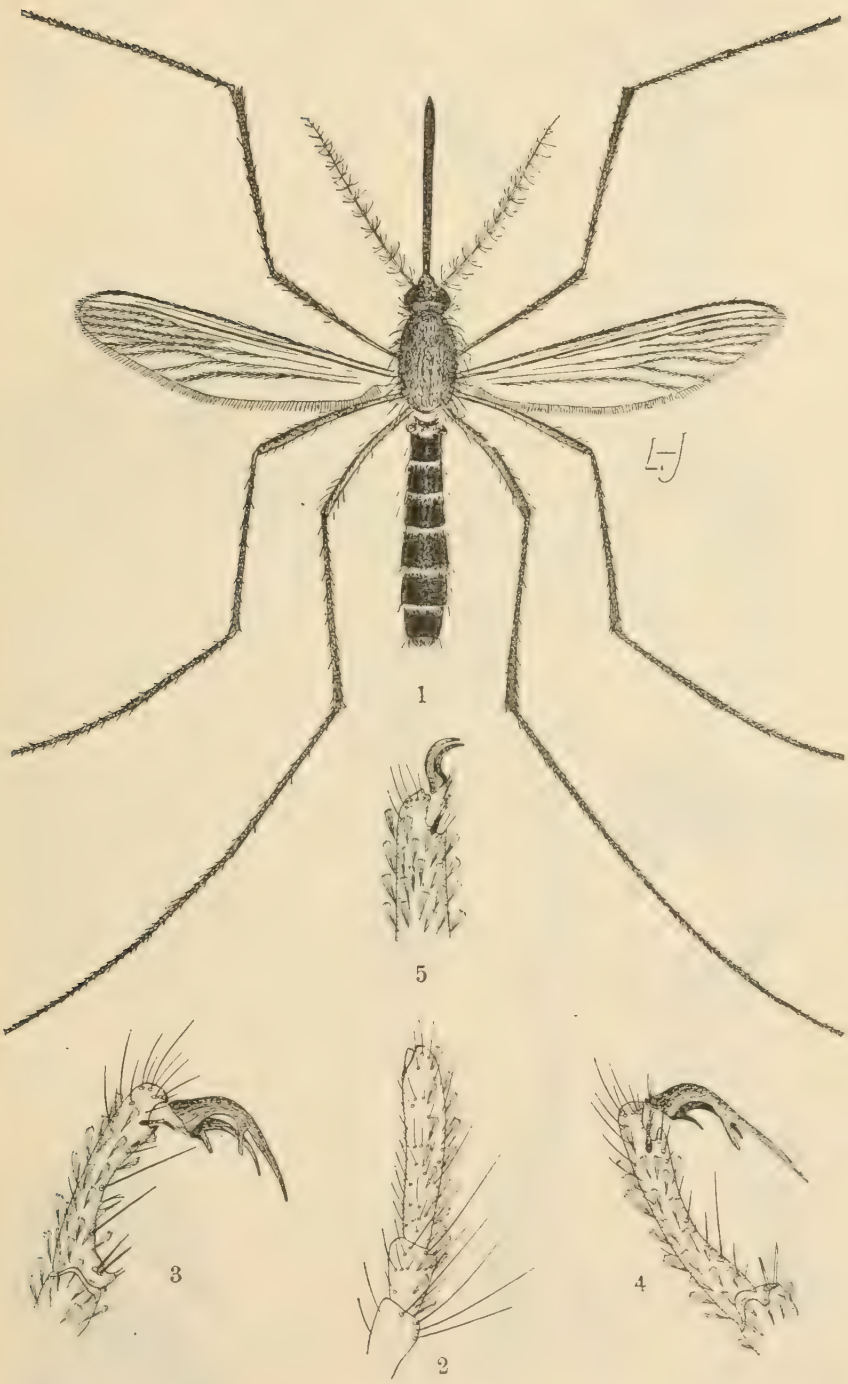


Fig. 46. Adult House Mosquito. (After John B. Smith).
1, adult female; 2, palpus of same; 3, anterior, 4, middle and 5, posterior claws of male (all enlarged).

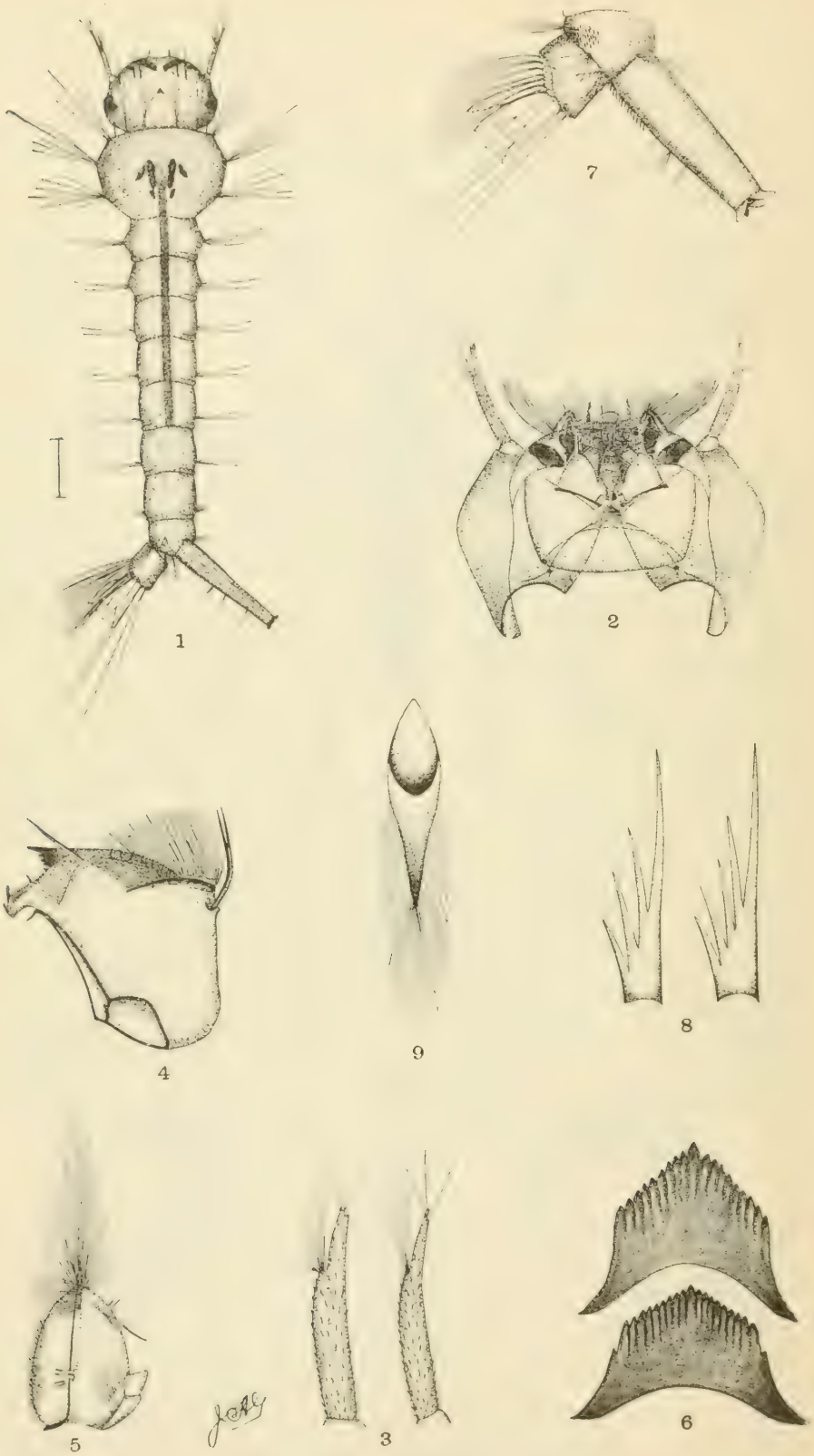


Fig. 47. Larva of House Mosquito. (After John B. Smith).

1, larva; 2, head below; 3, antenna; 4, mandible; 5, palpus; 6, mentum; 7, terminal segments with siphon; 8, siphonal spines; 9, single scale from 8th abdominal segments (all enlarged).

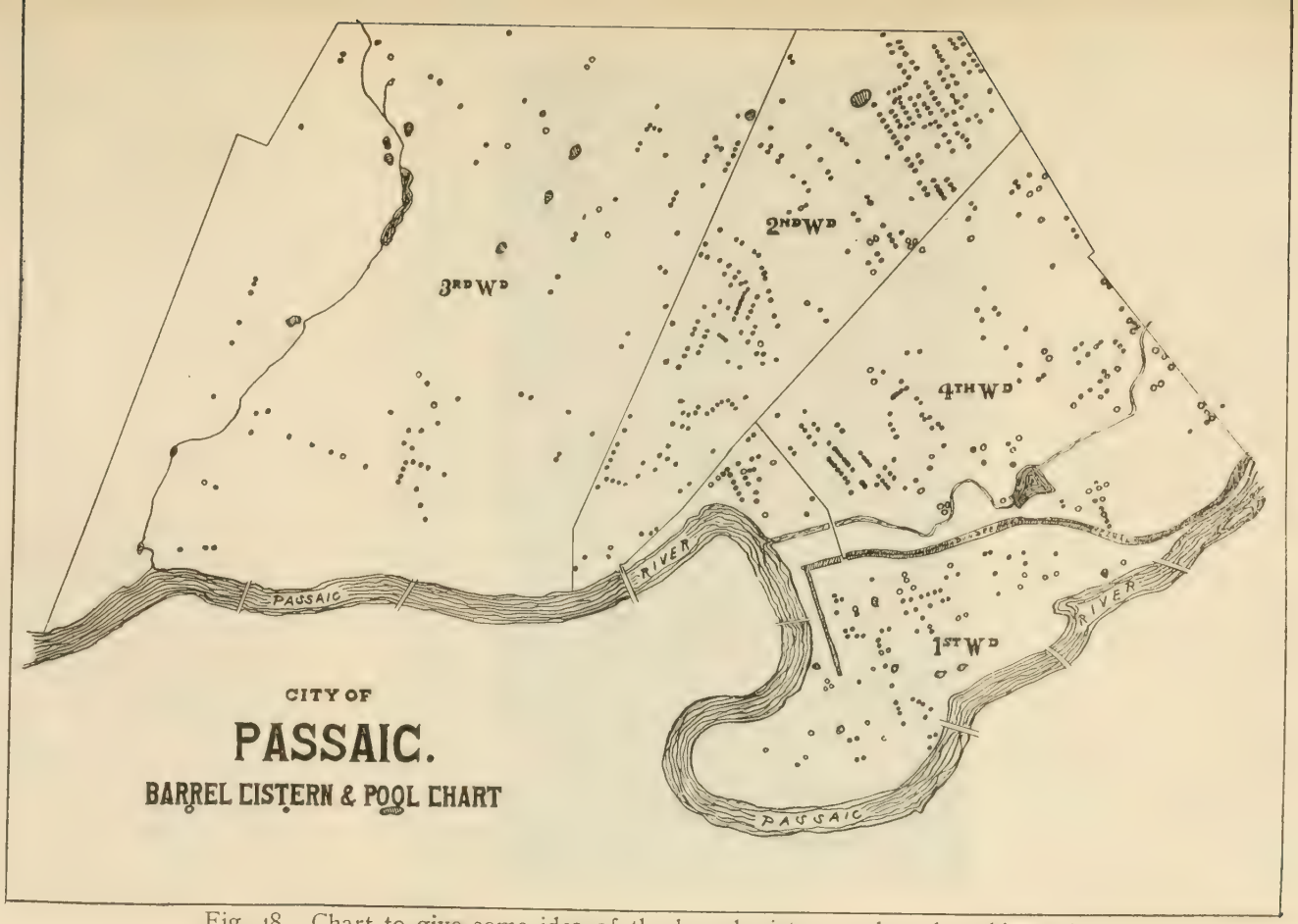


Fig. 48. Chart to give some idea of the barrel, cistern and pool problem of a city of 100,000 inhabitants. (After Passaic County Mosquito Extermination Commission).

Life Habits

Culex pipiens passes the winter as an adult female hiding away in cellars, buildings and other protected places. When warm weather definitely sets in the spring, the adults come forth and lay their eggs wherever standing water can be found. The eggs, which are black, are stuck together in such a fashion as to form a boat-shaped raft. Each raft is made up from 50 to 400 eggs. In about 24 hours after deposition the eggs hatch the wrigglers. In a week, if the water is warm and full of food, the wrigglers attain their growth and transform into the pupal stage. In this condition, without taking food, they stay from one to three days. Then the large end splits open and the mosquito crawls out. After resting for a short time on the old pupal skin and allowing the wings and body to expand and harden, the adult mosquito flies away. In a few days the females are ready to lay eggs. From the time breeding starts in the spring until the cold weather of fall drives the adult females into hibernation, brood succeeds brood.

Fig. 49. Typical breeding places of the house mosquito; pool and garbage dump—heavy breeding occurs both in exposed water and in receptacles. Open water can be effectively treated but only a small percentage of the receptacles can be reached. (Photo by Passaic County Mosquito Extermination Commission).

The type of rainy weather which will keep rainwater-holding places continually full without causing them to overflow and wash the larvae away is the weather most favorable to this species, for with heavy precipitation, no sooner does a brood get started than it is washed away. Extreme dry weather is likewise unfavorable,

for a very large proportion of the normal breeding places dry up. In certain localities where many brooks occur, the loss of normal breeding places through extreme dry weather may be more than compensated for by the reduction of the brooks to series of pools in which mosquitoes breed in enormous numbers.

The house mosquito is not thought to fly far—not more than a few hundred yards. Recently, however, evidence has been accumulated to show that where it breeds over a large area in countless numbers, it may infest adjacent territory for a distance of 2.5 miles.

Fig. 50. Typical breeding places of the house mosquito; old barrels are prolific breeders of mosquitoes. (Photo by Passaic County Mosquito Extermination Commission).

The White-Dotted Mosquito

(*Culex restuans* Theob.)

This species looks so much like the house mosquito that a magnifying glass is needed to detect the difference. Through the glass two perfectly round white dots can be seen on the thorax just in front of the base of a U-shaped white mark.

While the adults do not get into the houses so generally, they do accompany *C. pipiens* and occasion a considerable amount of suffering. With the exception of its habit of selecting clean water for breeding, its life history and habits are the same as those of *C. pipiens*. The larva is much like *C. pipiens* but differs in having the antennal tuft at a point less than half the distance from base to tip.

Control of the House-Mosquito Group

The formula for the control of this group—find all the water in which it breeds, and make it unfit for breeding by draining, filling, stocking with fish or the application of oil or larvicide—is as beautifully simple as the practical work is difficult.

Fig. 51. Typical breeding places of the house mosquito; sewage-charged marsh mosquitoes bred here very intensively and migrated a distance of at least 2.5 miles. (Photo by Essex County Mosquito Extermination Commission).

Satisfactory control of this group involves: (1) determination of the size of the area which must be covered; (2) location of all permanent breeding places; (3) provision for periodic inspection of the territory (4) provision for treatment of all breeding-water surfaces.

Determining the size of the area

The size of the area depends upon the relation of the group to be protected to large breeding places from which flights of mosquitoes may come.

If within a distance of 2.5 miles of the group there exist enormous areas of polluted stagnant water, an attempt to afford protection without considering these intensive and extensive breeding places is certain to be followed by failure unless some great natural barrier such as a mountain range, possibly wide open water or large dense population, is situated between.

Fig. 52. Typical breeding places of the house mosquito; yard litter often provides bad breeding places. (Photo by Atlantic County Mosquito Extermination Commission).

Survey and Mapping of Permanent Breeding Places

Once the size of the area has been determined it should be mapped and the permanent breeding places set down on the map. A report should be prepared setting forth the nature of this area with especial regard to the permanent breeding places, the method of permanently eliminating them and the estimated cost of the operation.

Creation of Organization to Carry Out Practical Work

Provision must then be made for an organization to examine the entire territory throughout the mosquito season at about ten-day intervals for mosquito breeding. Provision must be made for an organization to treat all breeding places found.

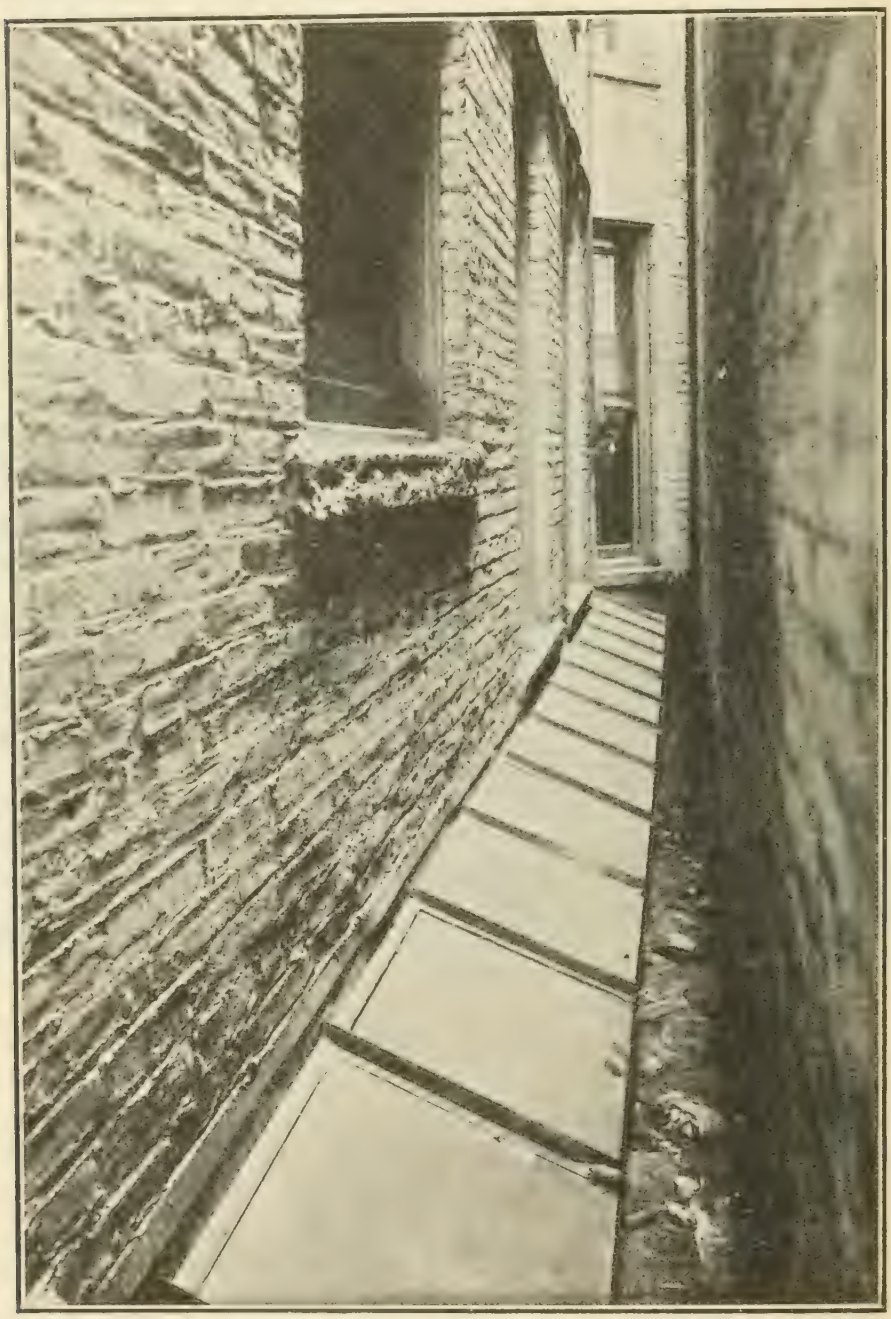


Fig. 53. Typical breeding places of the house mosquito; roof-gutter breeding. (After Essex County Mosquito Extermination Commission).

Evaluating the Effect of the Work in Terms of Density of Mosquitoes on the Wing

Some method of estimating the results in terms of mosquitoes found must be devised, and it is probable that regular weekly or semi-weekly night collections will serve the purpose. Depending upon the citizens' reports is very unsatisfactory, because they are usually widely divergent and in many cases diametrically opposed. The method of making and interpreting night collections is set forth in the following statements.

Fig. 54. An unusual breeding place of the house mosquito; sewage beds when water-logged become prolific breeders of mosquitoes. (Photo by Monmouth County Mosquito Extermination Commission).

There is no occasion to begin making evening collections until the breeding conditions indicate that mosquitoes are beginning to get on the wing or some adults are discovered incidentally. In the spring when we have the salt-marsh, the woodland-pool, and the fresh-water swamp species to deal with, daylight collections will be satisfactory, provided they are made in the same manner, at the same time and in similar (preferably weedy or shrubby) places. When, however, as in early summer the house mosquitoes must be taken in-

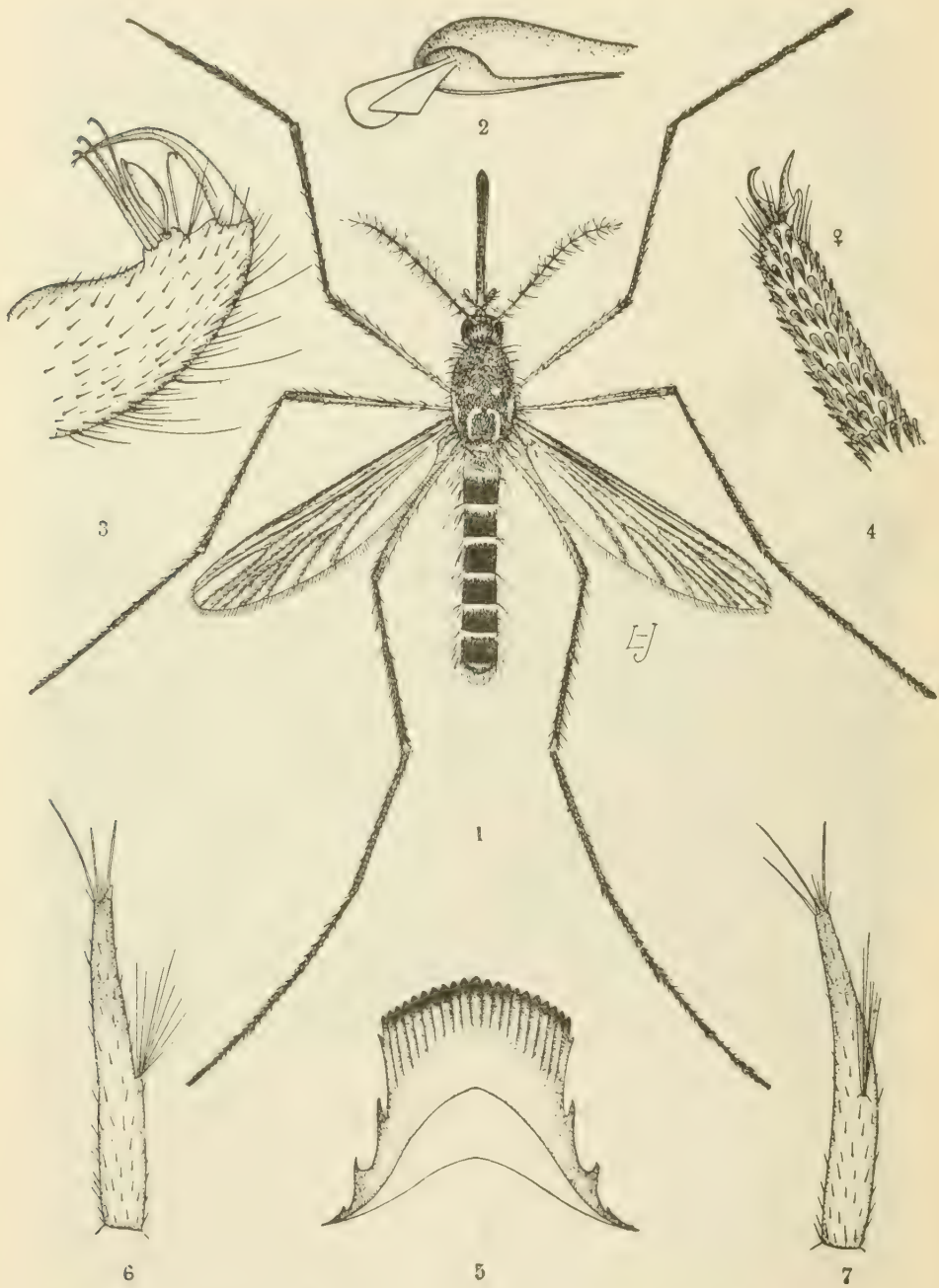


Fig. 55. Adult of White-dotted Mosquito. (After John B. Smith).

1, adult female; 2, appendage to tip of clasper; 3, clasper of male genitalia 4, anterior claws of female; 5, mentum of larva; 6, 7, antennae of the same (all enlarged).

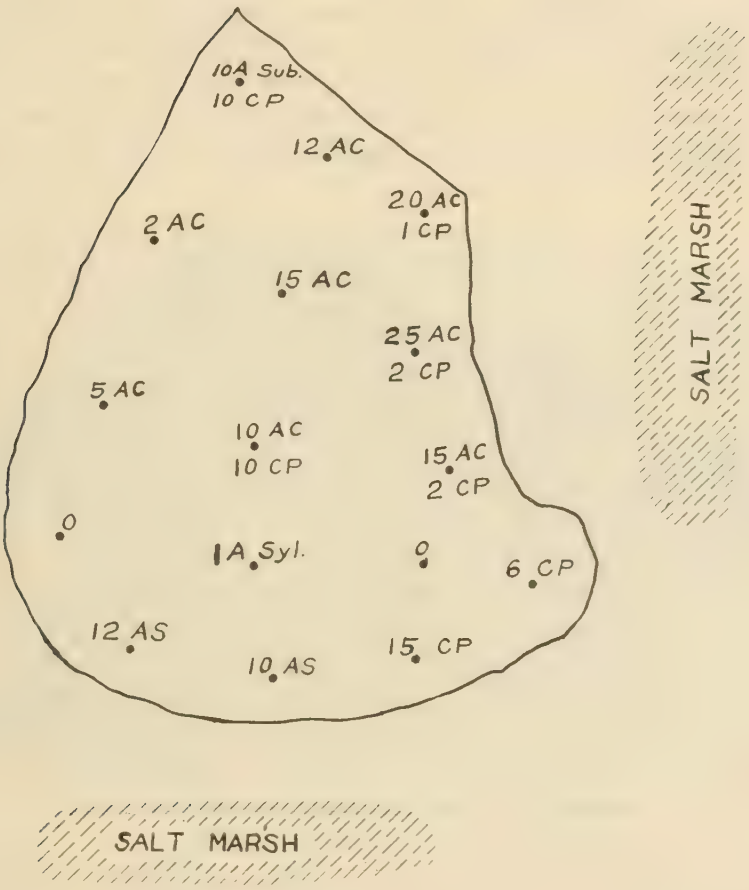


Fig. 56. A diagram to illustrate the method of determining mosquito conditions by evening collections of mosquitoes on the wing. The area enclosed in the solid black line is protected.

* = Collection stations.

Numerals = number of mosquitoes caught at each station.

AC = the brown salt-marsh mosquito (*Aedes cantator* Coq.,).

AS = the white-marked salt-marsh mosquito (*Aedes sollicitans* Wlk.).

A sub. = the brown woods mosquito (*Aedes stimulans* Wlk.).

A syl. = the fresh-water swamp mosquito (*Aedes sylvestris* Theob).

CP = the house mosquito (*Culex pipiens* Linn.).

Let us analyze this diagram and see what it means for each species. The brown salt-marsh mosquito shows heavily along the eastern border and decreases regularly to the west and northwest. Evidently a brood had invaded the area from the eastern border. Likewise a heavy infestation of the white-marked salt-marsh appears along the southern border and decreases regularly to the northward. Evidently there has been an invasion of this species from the southward. The distribution of the house mosquito is irregular, clearly indicating that overlooked local breeding is responsible. The occurrence of 10 brown woods mosquitoes at one collection station indicates the existence of local breeding. The occurrence of 1 swamp mosquito is too slight to be significant.

to consideration, the time of collection should be between 7.30 p. m. and 9 p. m. Each collector should spend at least 15 minutes in a place and one man may take care of two or even three places.

If the territory is large and the number of collectors small, one evening each week should be given to the county-wide collection and various limited portions of the territory should be attended to on the other evenings.

The number representing each species at each station should be determined on the following morning and the results set down upon a map of the area. If here and there over the map small isolated areas where mosquitoes are much thicker than elsewhere are found, these areas should without delay be most carefully searched for overlooked breeding. If areas of considerable size are found on the border or of large size well within the confines of the area, they should at once be further studied. If the species concerned belongs to the salt-marsh or fresh-water swamp or woodland-pool, daylight collections will serve to get at the facts, but if the house forms are to blame the examinations will have to be made in the evening. In either case, two lines of collection should be made—one running through the dense zone in one direction and the other at right angles. The direction in which the number of mosquitoes caught grows larger is the source of the brood and if the tracing is done promptly the larvae or pupae or pupal shells will be found where the brood in question matured. If not promptly traced the location of the source of brood may be found to be impossible.

It is thought that by use of these methods of collection the density of the mosquito fauna may be expressed in terms of so many mosquitoes a minute or other period of time, and that the number per minute, quantities above which mean trouble to the householder and below which mean freedom from trouble, will soon be determined for each of the species concerned. It is thought that experience will soon define the increase in number, which means that the fresh-water species, especially the house mosquito, is breeding unchecked and that more careful examination must be made. It is further thought that this increase may be detected early enough so that the breeding may be found and eliminated before the density of the fresh-water mosquito fauna becomes sufficient to trouble the householder. It is thought that the practice of these methods will enable the exterminator to run down accurately the breeding places from which the invasion of migrational mosquitoes come and thus to take the first necessary step toward their elimination.

A very satisfactory and simple method of keeping a record of the results of night collections is to be found in the practice of pinning the figures representing the results of a single evening collection on a map of the district being protected (the results at each station being pinned at a point on the map representing the spot where they were taken) and photographing the map thus decorated. Negatives or prints or both can then be filed for later reference.

Fig. 57. A night collection record. (Courtesy of the Union County Mosquito Extermination Commission).

The Malarial Mosquito Group

Only four species of the genus *Anopheles* have been definitely recognized as occuring in New Jersey: *A. barberi, A. crucians, A. punctipennis,* and *A. quadrimaculatus.* The first species has thus far proven of no economic importance and will be given only passing mention.

THE DAYLIGHT ANOPHELES

(*Anopheles crucians* Wied.)

This species, which is the least common of the important *Anopheles* known in New Jersey, may be distinguished from other *Anopheles* by the fact that the black scales are collected along the front margin and the wing spots mentioned as characteristic of the other species are absent.

This species, which is sometimes more troublesome than *C. pipiens,* is found in South Jersey, and Cape May County seems to be its real home. It breeds abundantly on the salt marsh and flies and bites freely during the daytime.

Fig. 58. Adult of the Daylight Anopheles. (After John B. Smith).

The Mottled-Wing Anopheles

(*Anopheles punctipennis* Say.)

This species may be distinguished from the other common *Anopheles* by the fact that the front wings show one large white spot in the front margin of each.

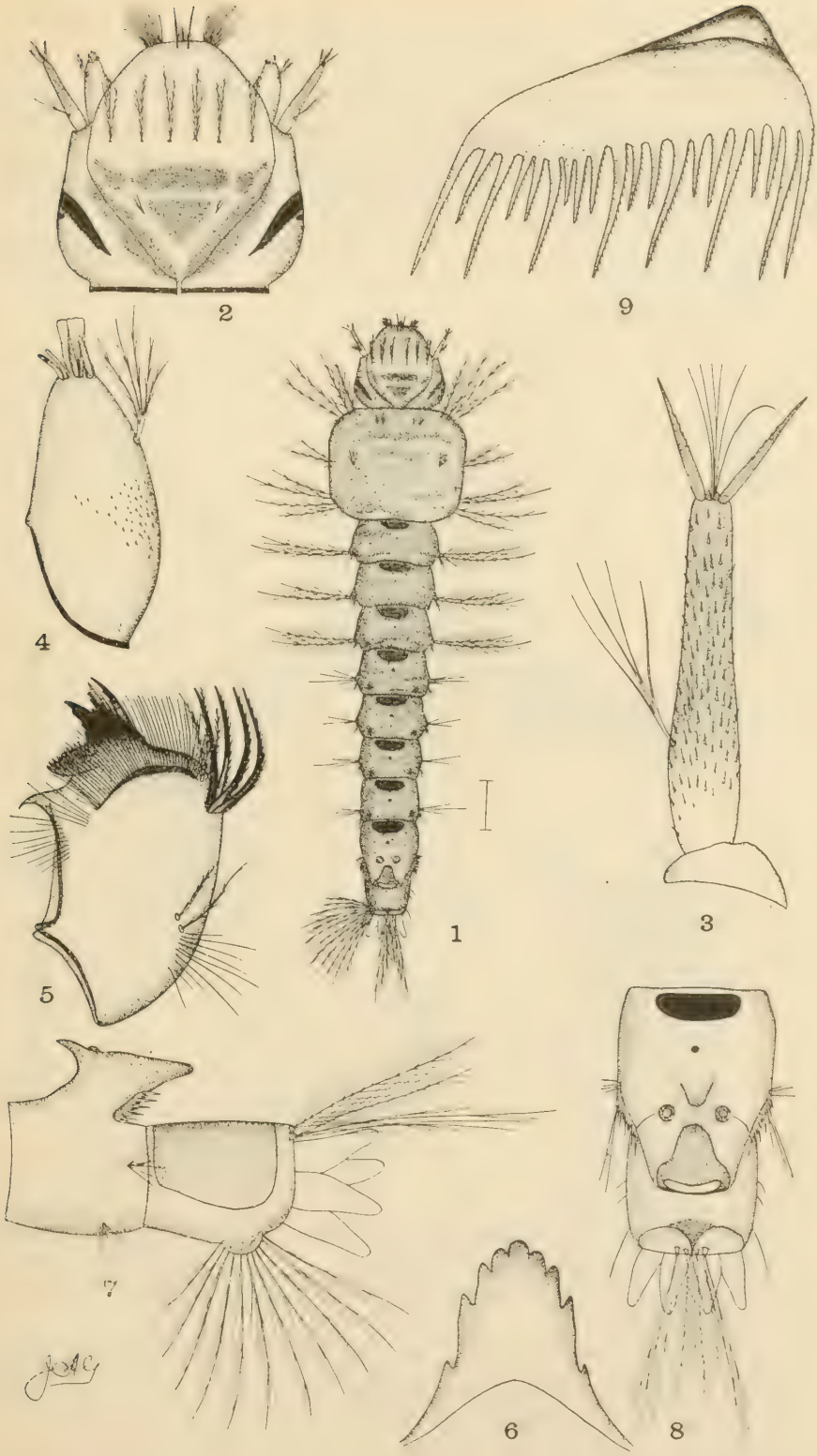


Fig. 59. Larva of the Daylight Anopheles. (After John B. Smith).

1, larva; 2, head from above; 3, antenna; 4, palpus; 5, mandible; 6, mentum; 7, anal segments from side; 8, anal segments from above showing spiracles; 9, one of the scales (all enlarged).

The larva is much like those of the other species of *Anopheles*. In importance this species does not compare with the one which follows, although recently King has shown that it is able to transmit the malarial parasite. Le Prince has reported that it does not

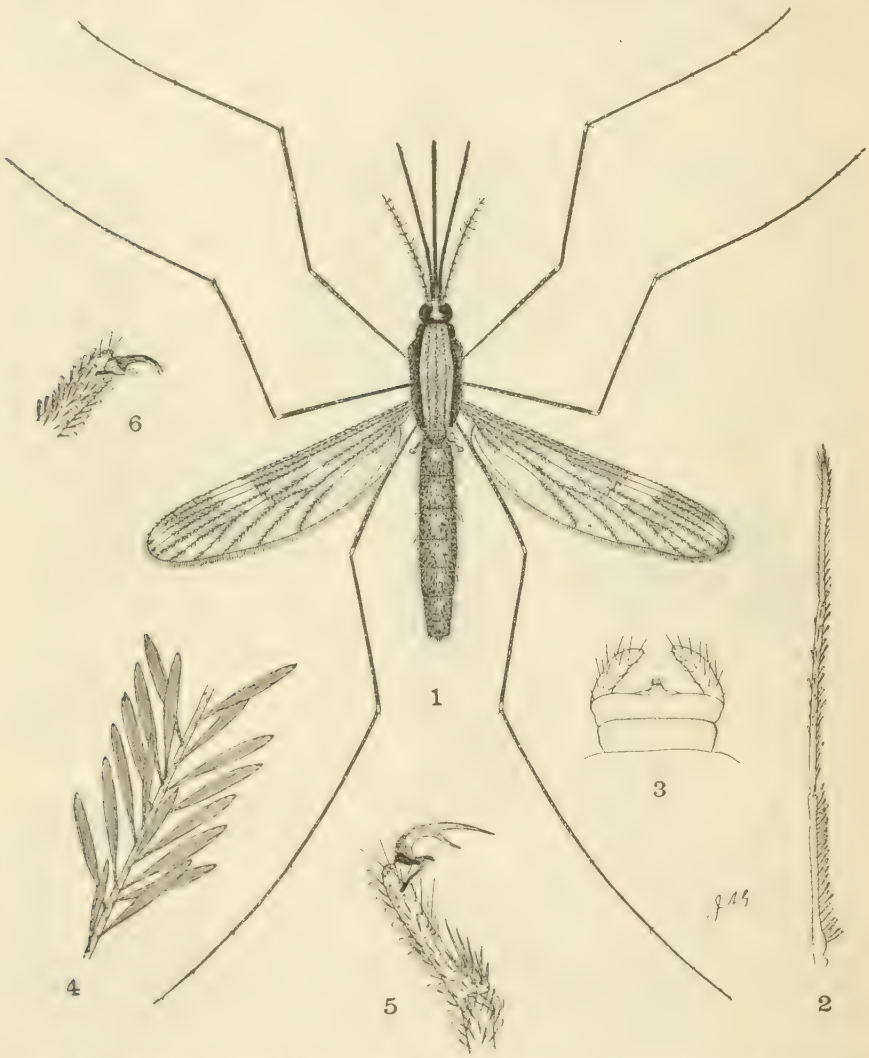


Fig. 60. Adult of the Mottled-Wing Anopheles. (After John B. Smith).

1, female adult; 2, her palpus; 3, genitalia; 4, part of wing vein showing scales; 5, anterior and 6, middle claws of the male (all much enlarged).

show the same fondness for entering houses that characterizes *A. quadrimaculatus*. This species occurs throughout the state while the disease of malaria occurs only in very limited areas. These areas are always marked by a great abundance of *A. quadrimacula-*

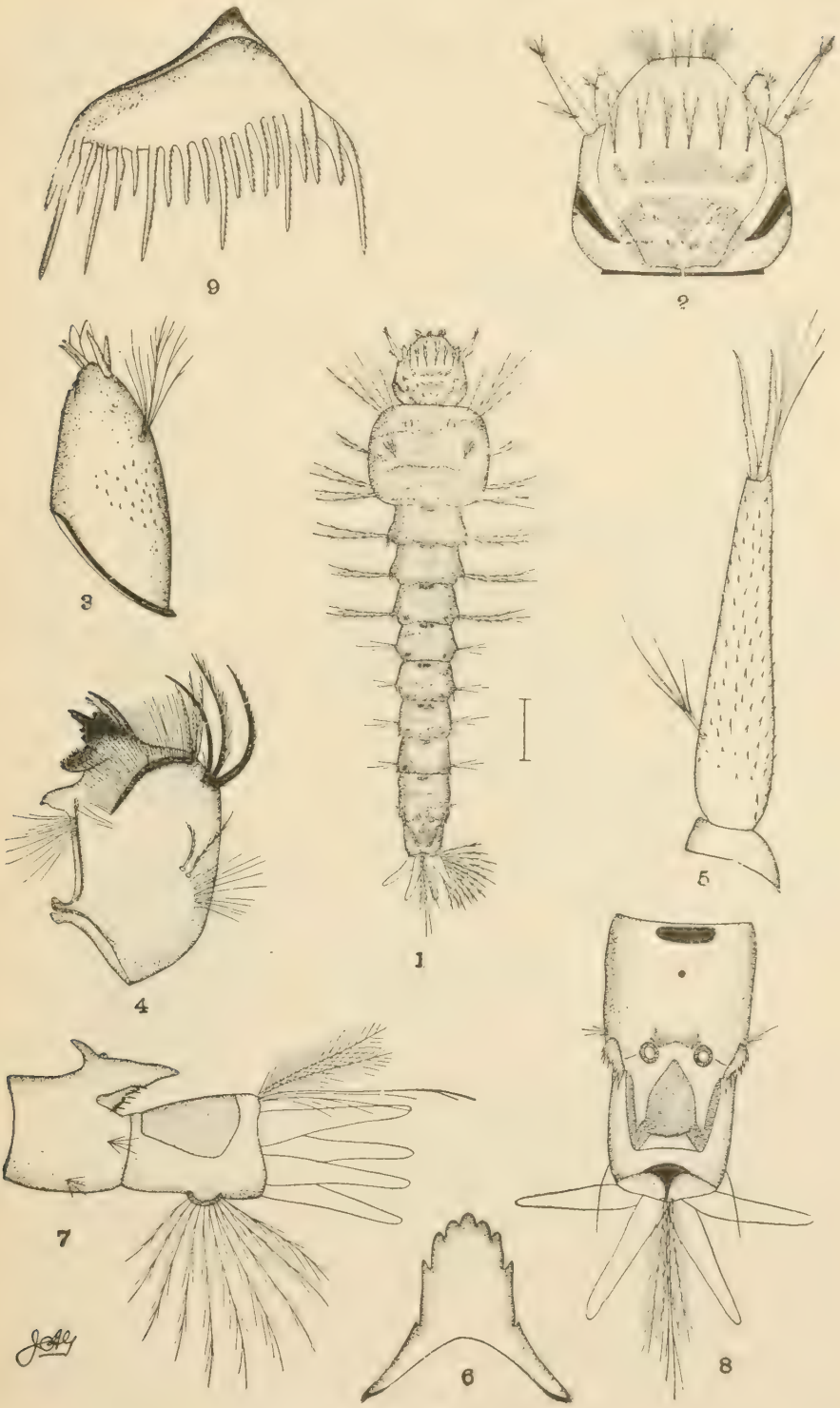


Fig. 61. Larva of Mottled-Wing Anopheles. (After John B. Smith).

1, larva; 2, head above; 3, palpus; 4, mandible; 5, antennae; 6, mentum; 7, anal segments from the side; 8, anal segments from above showing the two spiracles; 9, one of the scales (all much enlarged).

tus. It seems very much that, as the writer has heard Dr. Henry R. Carter explain it, "*A. punctipennis* can carry the disease of malaria but usually does not."

In life habit this species is very similar to *A. quadrimaculatus*, except that its breeding is apparently a little more strictly confined to fresh water.

The Malarial Mosquito

(*Anopheles quadrimaculatus* Say.)

Recognition Marks

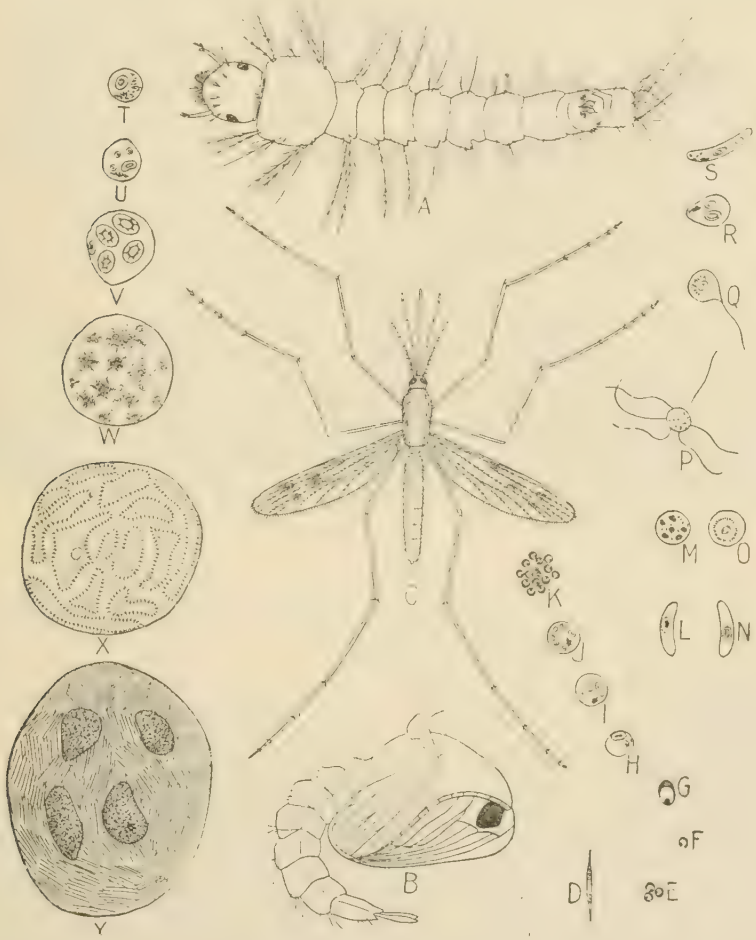
The genus to which this species belongs (*Anopheles*) may readily be distinguished from all other genera by the fact that the palpi (slender organs found one on each side of the beak) are about three-fourth as long as the beak; while the same organs in the females of other species are hardly one-fourth the length of the beak. This species may be distinguished from other species of *Anopheles* by the fact that it is brownish in color and has four brownish spots on each wing. The larvae (wrigglers) of this and the other species of *Anopheles* are easily distinguished from the young of other species by the fact that they have almost no apparent breathing tube, and the position assumed when securing air is parallel and close to the surface of the water, while the other common species, as a rule, have long breathing tubes and assume an oblique position to the surface of the water.

Importance

It has apparently been demonstrated beyond all doubt that the disease known as human malaria is under all ordinary conditions transferred from persons having the malarial parasite in their blood to persons free from such infection by this mosquito and that the transfer occurs through no other agency. In New Jersey the distribution of the disease is such as clearly to indicate this species as the carrier and to indicate that it is responsible for the spread of malaria (when such occurs) in this state.

This species occurs all over the state, but abundantly only in the central and northern portions. The malarial cases reported are, for the most part, likewise found mostly in the central and northern portions.

The total number of cases of malaria in the state as a whole is not large—484 cases in 1912 and 614 cases in 1913—but when we consider the distribution of these cases (366 in 1912 and 331 in 1913, in one county), the number is far too large. We should have



Anopheles and Malaria: *a*, larva; *b*, pupa; *c*, adult; *d*, the blast introduced into the blood by the mosquito; *e* to *j*, stages through which the Plasmodium passes in the red blood-corpuscles; *k*, the spores which enter new blood-corpuscles; *l*, *m*, the microgamete; *n*, *o*, the macrogamete; *p*, flagellae forming; *q*, union of a flagellum with a macrogamete; *r*, fusion of nuclei; *s*, the vermicule; *t* to *y*, formation of the zygote in the mosquito stomach; the fully developed zygote, *y*, rupturing to produce blasts.

Fig. 62. The Malarial Parasite and its life cycle. (After John B. Smith).

no new cases among persons living constantly in the state. In at least one district in New Jersey, malaria appears as regularly as the season. In other localities where it occurs at all it comes at intervals only. Either the malarious subject or the mosquito is absent during

the years when it is unknown, and both are present when an outbreak occurs.

A. quadrimaculatus, the real malarial mosquito of New Jersey, in its efforts to obtain food, draws the parasite, which causes the disease, along with the blood of the malarious person whom it chances to bite. The parasite undergoes certain growth stages in the mosquito's body and finally reaches a stage of development when it is injected into the feeding wound along with the mosquito's saliva. This places the parasites in the blood stream where they may attack the red blood corpuscles, initiating that series of changes that brings chills and fever.

Life Habits

Like *C. pipiens,* this species passes the winter as an adult female in cellars and other sheltered places. Breeding of this species becomes noticeable somewhat later than that of *C. pipiens.* The eggs are laid singly or loosely grouped on the surface of the water. From fifty to seventy-five seems to be the usual number. In about 48 hours the wrigglers emerge and begin feeding. In from 7 to 10 days in mid-summer or twice that time in spring and fall, the wrigglers become fully grown and transform to pupae. In from 1 to 3 days the adult emerges from the pupal skin. Breeding is as continuous from spring until fall as the temperature and moisture conditions will permit.

This species seems to be quite as eager as *C. pipiens* in penetrating human dwellings, and even more successful. According to Dr. Smith[6] although there were at least 100 *C. pipiens* for each *Anopheles* developing in New Brunswick in 1903, there were quite as many *Anopheles* as *C. pipiens* in his bedroom.

Control of the Malarial Group

The problem of control in the malaria group is much the same as in the house-mosquito group except that present knowledge of the flight range (according to Le Prince slightly over a mile) renders the problem more local in nature and the greater facility with which it uses wild and unpolluted, and brackish water makes necessary close attention to streams and swamps within flight range.

At this point the writer wishes to state that not enough study has been giving to the flight habit of the Anopheline mosquitoes occuring

[6]Smith, J. B. 1904. N. J. Agr. Exp. Sta., Report on Mosquitoes, p. 159.

A

B.

Fig. 63. Typical breeding places of the malarial mosquito. (After John B. Smith).

within the borders of the state and that further studies are certain to modify ideas of control. The ordinary evening collection does not usually show the presence of *A. quadrimaculatus* except as the collector is located very close to the place of breeding. This is true although the distribution of the mosquito may be general over the territory when collections are being made. The best place to look for specimens of *A. quadrimaculatus* is inside the houses, where it sometimes is found concentrated although it may be scarce outside.

The Swamp-Mosquito Group

This is not a well defined set of species, for some members of the group take on the habits at times of woodland species. *Aedes sylvestris* Theob. is probably the most important and certainly the most typical member of the group. *Mansonia perturbans* Wlk. comes next in point of importance.

The Swamp Mosquito

(*Aedes sylvéstris* Theob.)

Recognition Marks

This species is a medium-sized or small mosquito with unbanded beak and unspotted wings. The tarsi are narrowly white banded at the base. The abdominal segments have bands of pure white at their bases, which, with the exception of the first two and the last two, are so strongly constricted at their centers as to appear almost divided.

The larva is variable in color but usually shows the head marked with spots, the arrangement of which is characteristic (fig. 65). Its antennae rise from the sides of the anterior part of the head. The breathing tube is 2½ to 3 times as long as broad. There are 4 tracheal gills. The 10 to 15 scales on each side of the eighth abdominal segment are individually separate and arranged in a partially double row.

Importance

This mosquito occurs in all parts of the state but is most abundant in the non-sandy regions. Its abundance is subject to great

seasonal variation. Starting with a spell of very wet weather in 1916 it became the dominant species in all counties with non-sandy soil where mosquito-control work was going on and remained so throughout 1917. In 1918 it returned to its former status as a main constituent of the mosquito fauna but in 1919 it seemed in the way of resuming the prominent position which it held in 1916 and 1917. The cause of this variation is unknown.

Fig. 64. Adult of the Swamp Mosquito. (After John B. Smith).
1, female adult; 2, anterior; 3, middle and 4, posterior claws of the male (all much enlarged).

In 1917 it bred during the month of June in enormous numbers over the flooded areas of the upper Passaic Valley, and on emerging made its way eastward and south-eastward through the gaps of the mountains in some cases for a distance of 10 miles.

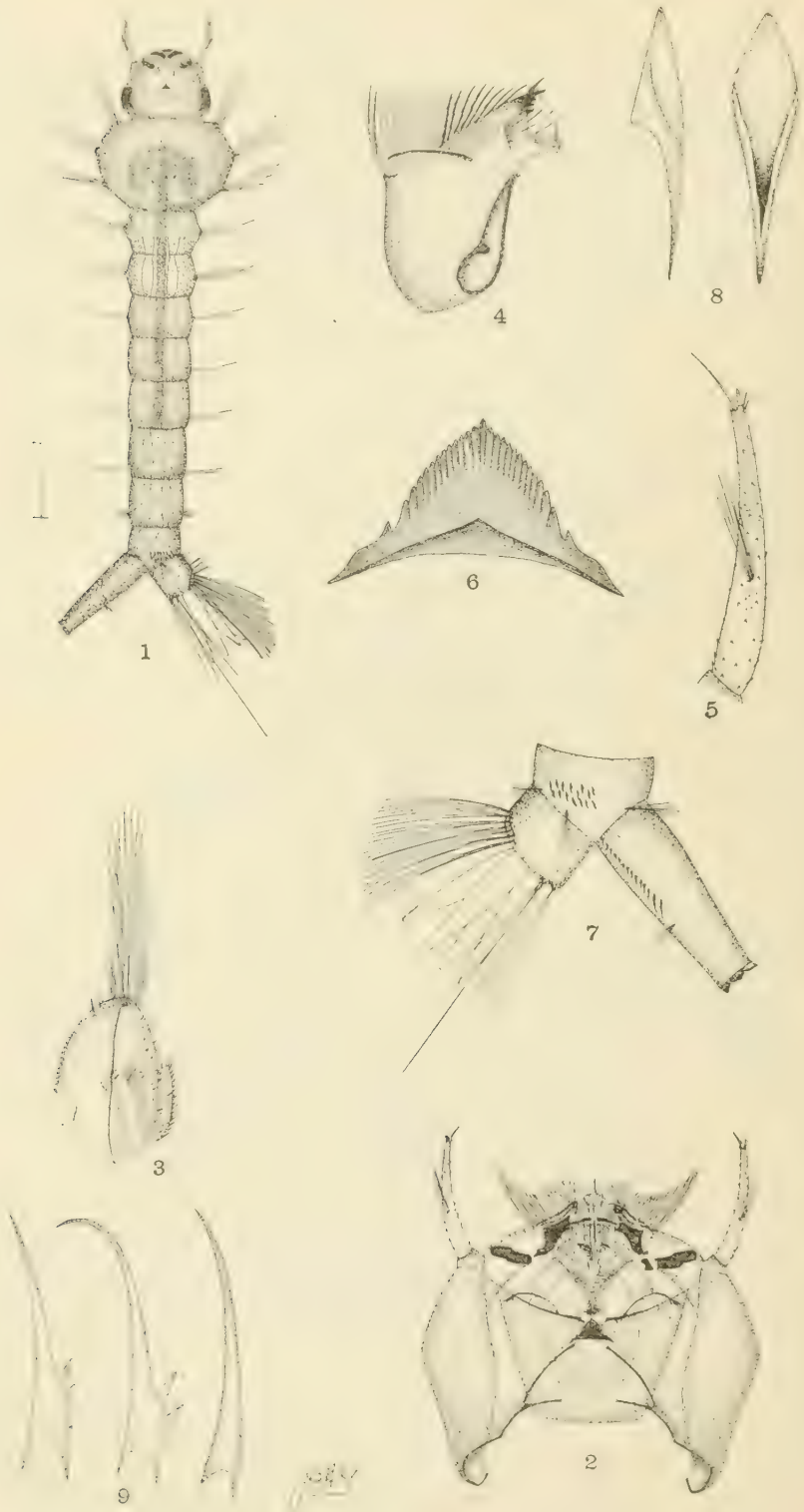


Fig. 65. Larva of the Swamp Mosquito. (After John B. Smith).

1, larva; 2, head from below; 3, palpus; 4, mandible; 5, antenna; 6, mentum; 7, terminal joints and siphon; 8, single scales from below and side; 9, siphonal spines showing variation (all much enlarged).

Life Habits

The swamp mosquito winters in the egg stage at the bottom of the pools in which it normally breeds. Early in the following spring the eggs begin to hatch and from that time on, if the pools are not dried up, larvae may be found. The eggs appear to hatch unevenly,

Fig. 66. Typical breeding place of the swamp mosquito. (Photo by Union County Mosquito Extermination Commission).

and the complete development of the first brood covers a long period. One brood succeeds another as rapidly as the weather and water supply will permit.

Breeding may occur in almost any water except that which is brackish or positively foul. In woodland pools the number of *A. sylvestris* larvae is second to *A. canadensis* and in open swamp areas they are more abundant than any other species.

THE IRRITATING MOSQUITO

(*Mansonia perturbans* Wlk.)

Recognition Marks

This is a large brown mosquito whose tarsi show a broad white band at the base of each segment and a broad band of the same color beyond the middle of the tibia whose beak is ringed with a

broad white band placed about half-way between tip and base, and whose abdominal segments each show an indistinct narrow white band along its base.

The larva differs from those of all the other common species in its habit of staying at the bottom attached to grass roots. It is a light colored, robust wriggler with a bottle-shaped breathing tube.

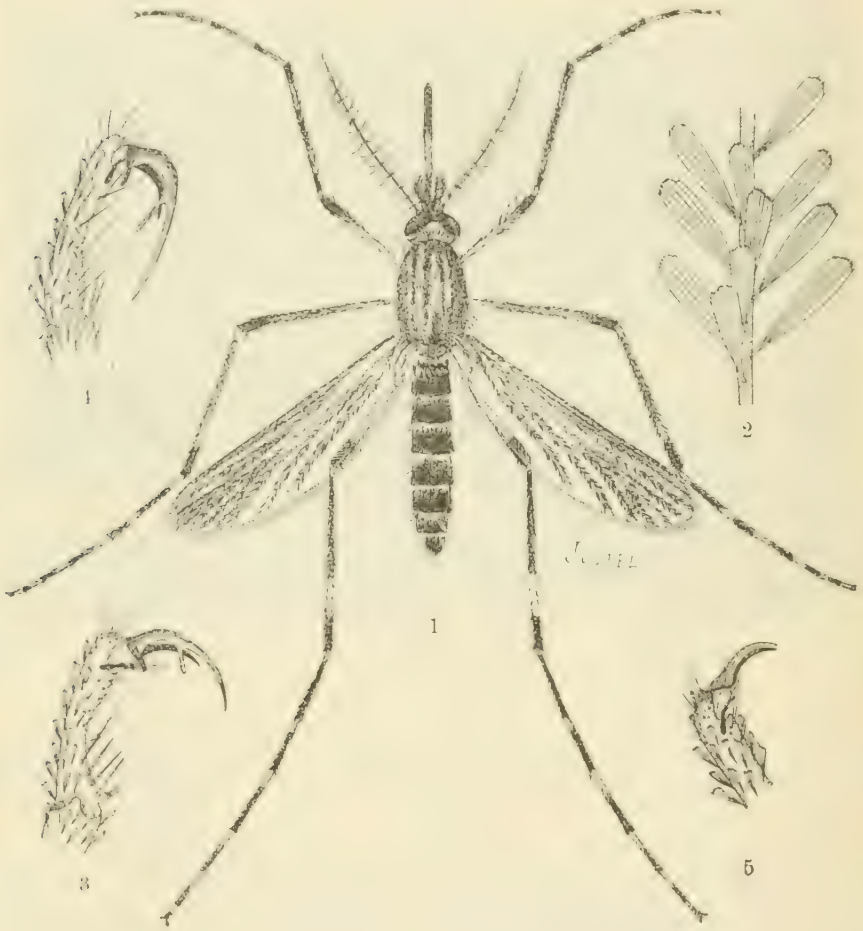


Fig. 67. Adult of the irritating mosquito. (After John B. Smith).
1, female adult; 2, part of wing vein showing scales; 3, anterior; 4, middle; 5, posterior claws of male tarsi (all much enlarged).

Importance

This species occurs throughout the state, and locally in tremendous numbers. It is perhaps the fiercest biter among the mosquitoes of New Jersey, and when present in large numbers renders being out during twilight unbearable. Fortunately, it rarely comes in large numbers.

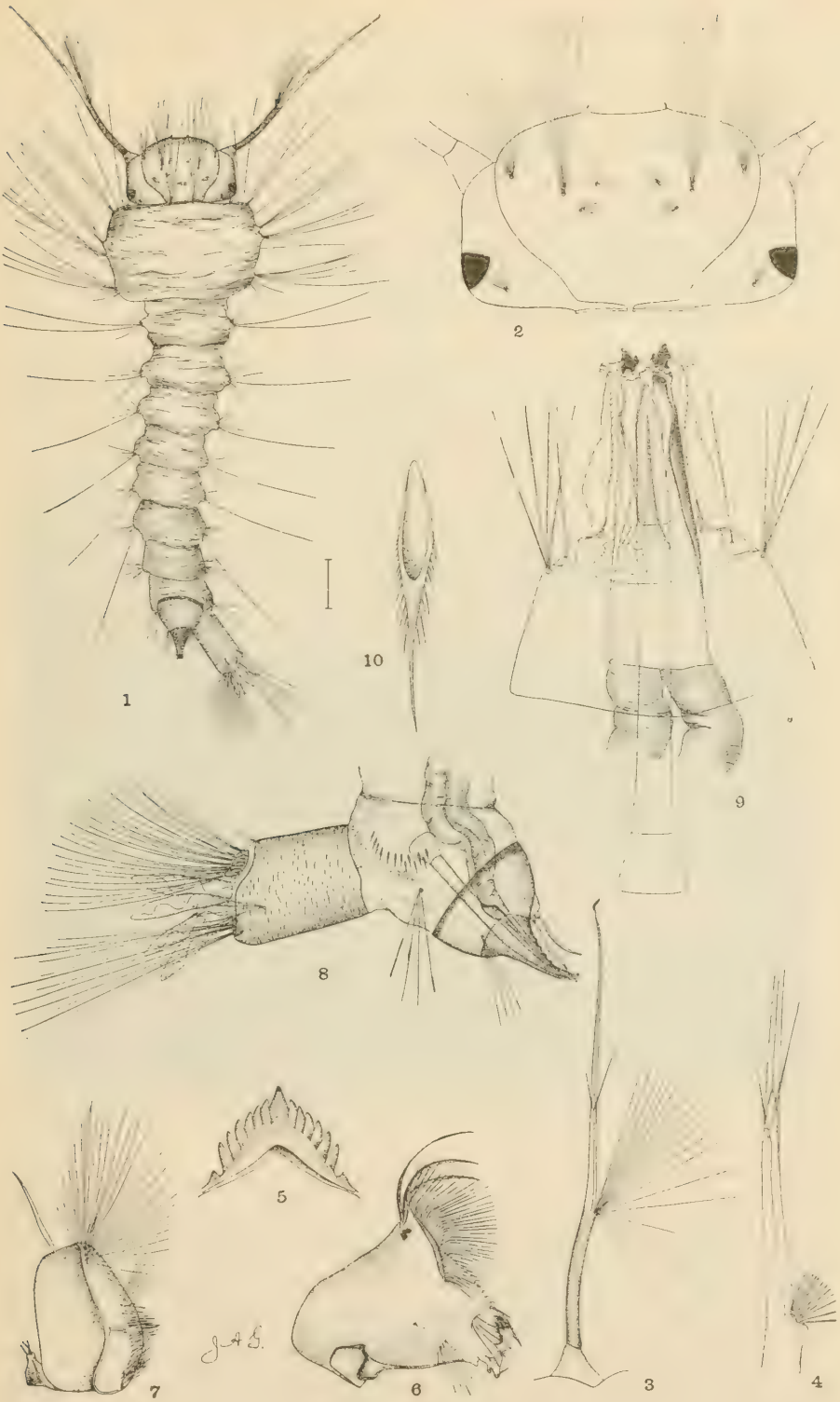


Fig. 68. Larva of the Irritating Mosquito. (After John B. Smith).

1, larva in 4th stage; 2, head showing position of hair tufts; 3, antenna; 4, part of the same, yet more enlarged; 5, mentum; 6, mandible; 7, maxillary palpus; 8, caudal segments of larva; 9, anal siphon; 10, a single lateral scale (all enlarged).

Life Habits

To J. Turner Brakeley belongs the credit of having first worked out many of the life habits of this mosquito. Mr. Brakeley's observations, as recorded by Dr. J. B. Smith,[7] covered a period of 1 year and demonstrated: (1) that there is only one brood; (2) the larvae hibernate and remain attached to the mass of roots of aquatic plants even when the water freezes solid; (3) neither larvae nor

Fig. 69. Typical breeding place of the Irritating Mosquito. (After John B. Smith).

pupae normally ever come to the surface; (4) egg-laying begins while a considerable percentage of the previous season's larvae are still immature; (5) adult mosquitoes begin to appear early in June and continue to come in noticeable numbers throughout the season.

The irritating mosquito breeds mostly in swampy places. The habit of the larvae and pupae of securing their oxygen supply without coming to the surface renders the immature stages of this species radically different from nearly all others.

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[7]Smith, J. B., 1908. Report on the mosquito work for 1908. *In* N. J. Agr. Exp. Sta. 29th Ann. Rpt., p. 412.

CONTROL OF THE SWAMP-MOSQUITO GROUP

The control of this group differs from that of the house group, and drainage must necessarily play a large part. Breeding occurs over much larger areas where larvicides could be only slightly effective. Furthermore, *M. perturbans* can not be killed with oil because neither larvae nor pupae come to the surface for air. Nothing but a substance that mixes with the water can be successfully used. The type of inspection necessary to find breeding of this species is radically different. One must pull up the tussock-forming grasses growing in the suspected place and look for the larvae fastened to the roots. Sometimes the larvae can be scraped off the mud with a dipping net after the tussock grass has been pulled away.

Fig. 70. Typical breeding place of the Woodland-Pool Mosquito.

The Woodland-Pool Mosquito Group

This, like the swamp group, is somewhat loosely defined, for certain species that generally breed in woodland pools, under some conditions, breed in more open places. In general, however, the woodland group winters in the egg stage, produces a large brood early in the season, and stays close to the place where larval life was passed. Man is troubled by them only as he builds nearby or otherwise penetrates their haunts when they are on the wing.

Aedes canadensis Theob. is perhaps the most important member of the group. It is followed closely by *Aedes stimulans* Wlk. and *Aedes abfichii* Felt.

The Woodland-Pool Mosquito

(*Aedes canadensis* Theob.)

Recognition Marks

This mosquito has a white band at the base and tip of each tarsal segment except the last, the whole of which is white. Its beak is black, its thorax brown without bands, and its wings are unspotted.

The medium-sized larva ranges from light in its younger stages to dirty slate gray at maturity. Until two-thirds grown, the wriggler shows a characteristic transverse pale band at the neck. The head is usually very dark in color, almost black. The unmarked antennæ arise from the sides of the anterior part of the head. The 25 to 50 scales, which decorate each side of the eighth segment, are separate and elongated. The breathing tube is 2½ to 3½ times as long as broad, only the terminal segment has a dorsal plate or ring. Three other comparatively rare species so closely resemble *A. candensis* that where doubt exists the tables must be used to distinguish.

Importance

None of the woodland species have been very important until recent years, because comparatively few dwellings were placed within their reach. However, in the process of providing country homes, commuters have built many dwellings in reach of this species, and its ability to trouble the occupants has caused it to assume far greater importance than was formerly accorded to it.

Life Habits

The winter is passed in the egg stage, and hatching occurs very early (in some cases during the early part of February). The young larvae escape freezing by burying themselves in the mud. Hibernating eggs appear to hatch between February 1 and May 10. Of the eggs laid in May, a fair percentage hatch in June and give a second brood. When this brood produces eggs, a portion develops the

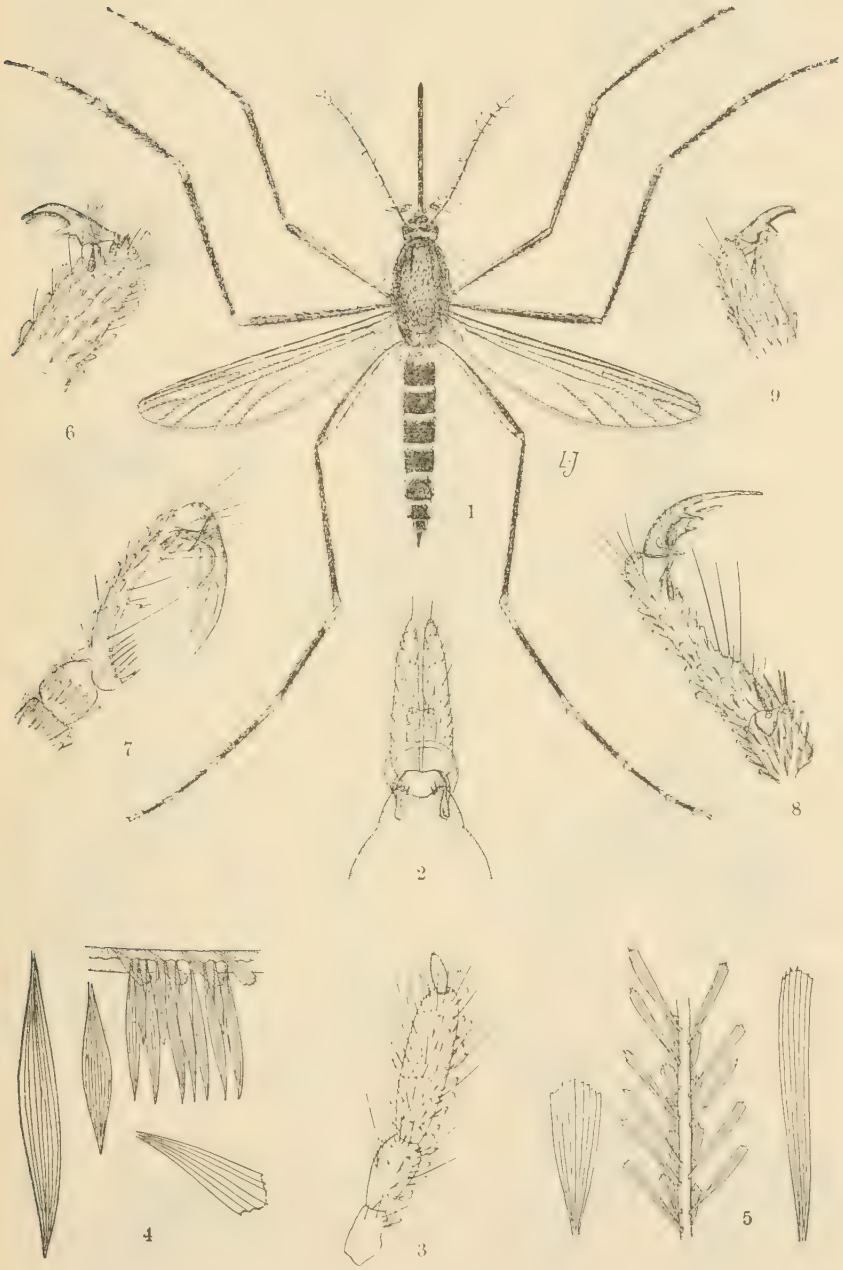

Fig. 71. Adult of the Woodland-Pool Mosquito. (After John B. Smith).

1, female adult; 2, ovipositor; 3, palpus; 4, margin of the wing showing the fringe scales; 5, part of vein showing scales; 6, anterior claws of female; 7, anterior; 8, middle and 9, posterior claws of male (all enlarged).

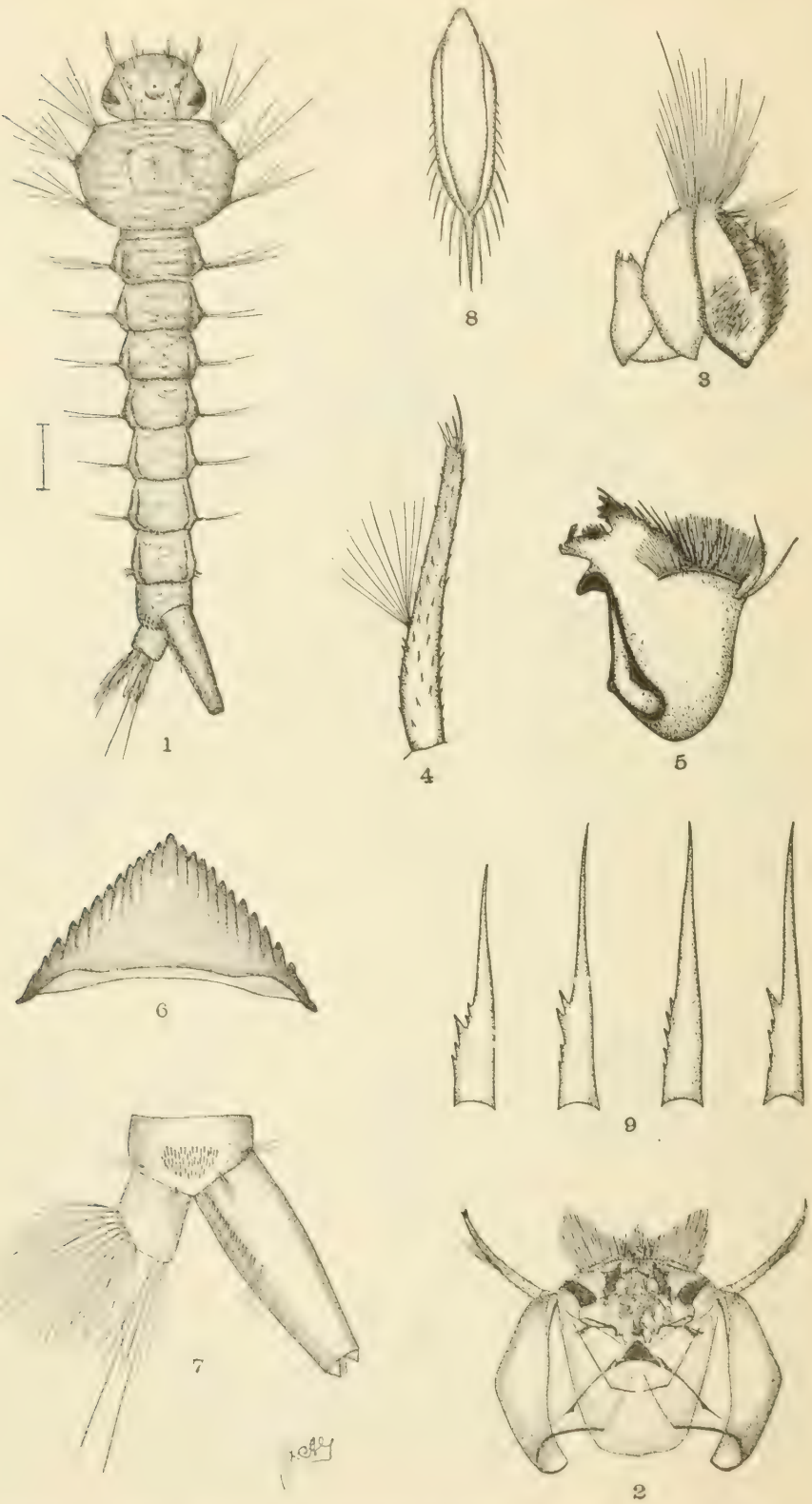

Fig. 72. Larva of the Woodland-Pool Mosquito. (After John B. Smith).

1, larva; 2, its head beneath; 3, maxillary palpus; 4, antenna; 5, mandible; 6, mentum; 7, terminal segments and siphon; 8, a single scale of the 8th segment; 9, siphonal spines showing variation (all enlarged).

next brood, and so on until fall. By this means, eggs sufficient for an enormous spring brood are provided.

This is not only one of the earliest species on the wing, but the number produced during the early spring makes it the dominant form. As the summer goes on the numbers decrease.

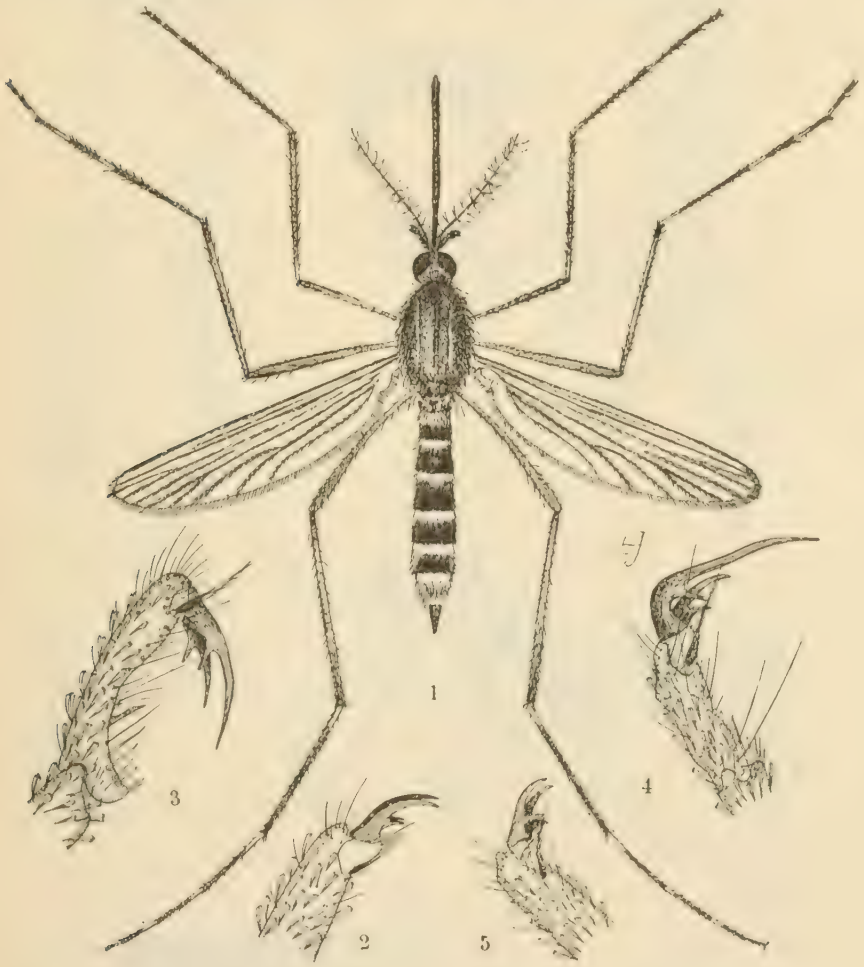

Fig. 73. Adult of the Brown Woods Mosquito. (After John B. Smith). 1, female adult; 2, the anterior claws; 3, anterior; 4, middle and 5, posterior claws of male (all enlarged).

THE BROWN WOODS MOSQUITO

(*Aedes stimulans* Walker)

This species resembles *A. cantator* and is easily mistaken for it. The white band at the base of each tarsal segment, except the last, is

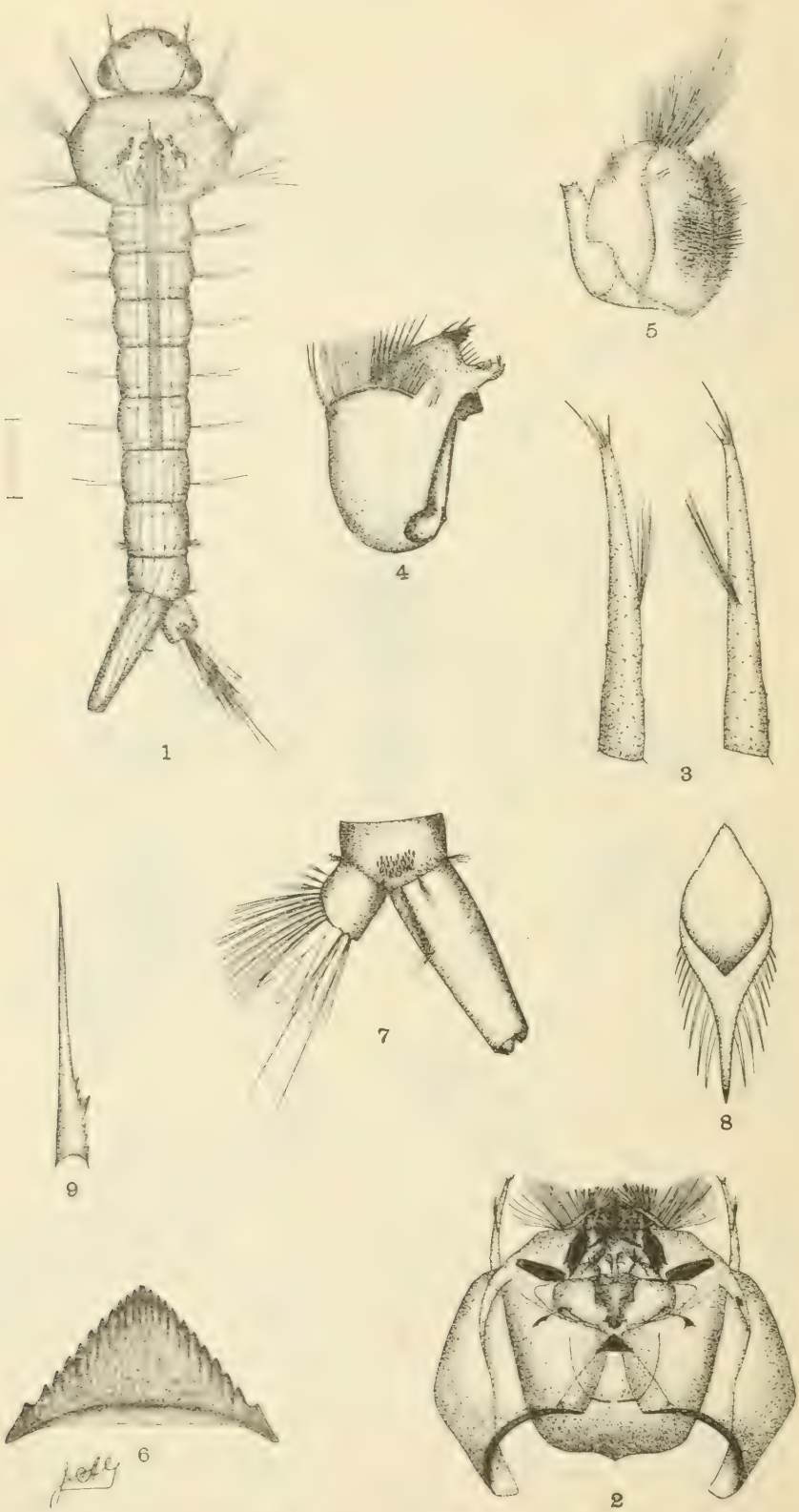

Fig. 74. Larva of the Brown Woods-Mosquito. (After John B. Smith).

1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal joints and siphon; 8, a single scale from 8th segment; 9, siphonal spine (all enlarged).

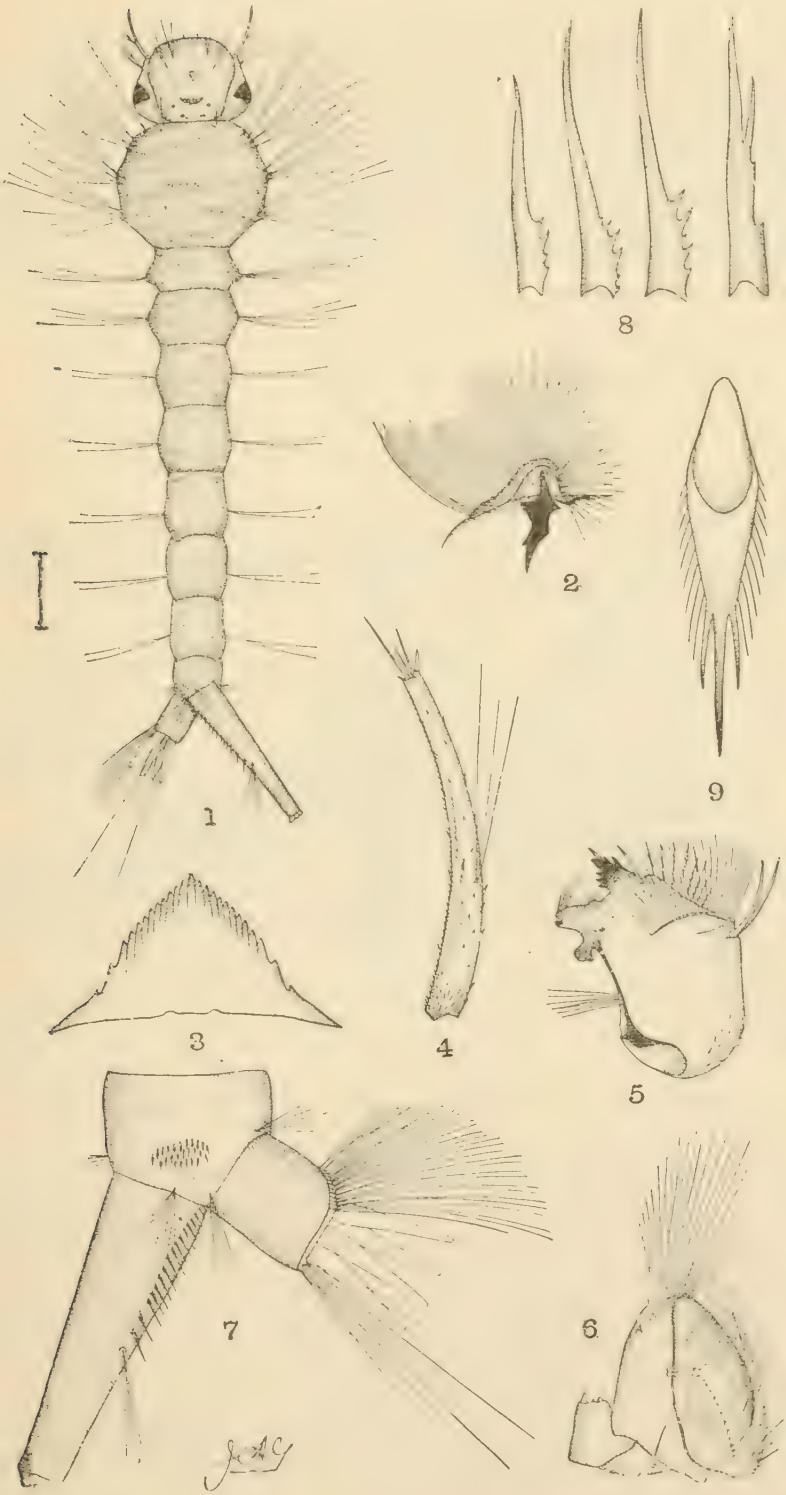

Fig. 75. Larva of the Brown-striped Woods Mosquito. (After John B. Smith)

1, larva; 2, the mouth brush; 3, mentum; 4, antenna; 5, mandible; 6, maxillary palpus; 7, terminal segments and siphon; 8, siphonal spines; 9, a single scale of 8th segment (all enlarged).

broader. The white bands on the mid-tarsi are narrower than those on the rear tarsi and are almost lost on the anterior ones. The white band at the base of each abdominal segment is also broader. The beak is unbanded and the wings are unspotted. Each hind tarsal claw shows a distinct tooth. The larva is very much like that of *A. cantator*, which has already been described, but differs in having a plain, unmarked head and by occurring exclusively in fresh water. Its habits are very similar to those of *A. canadensis*.

The Brown-Striped Woods Mosquito

(*Aedes abfitchii* Felt.)

This mosquito is much like *A. stimulans*, but differs in that it is smaller and darker, and in that it has a brown line in the middle of the thorax. Also it differes in that the abdominal bands are grayer and more diffused.

This medium-sized larva has a long breathing tube (5 times as long as broad). The antennal tuft is located at a point which is less than one-half the distance from base to tip of the antenna. There are from 24 to 30 scales on each side of the eighth abdominal segment and the antenna does not arise from an offset.

In the Great Piece meadows, and in certain timbered parts of Pequest river, in Warren County, this species appears in swarms. In the year 1907 it appeared in considerable numbers at Livingston Park and at Short Hills.

The life habits, so far as known, are similar to those of *A. stimulans*.

Control of the Woodland-Pool Mosquito Group

The control of this group is relatively simple with the possible exception of *A. stimulans*. It is usually necessary to oil the woodland pools which lie near human habitation, in the spring just before the adults are ready to emerge, and the group is taken care of for the season. *A. stimulans*, however, seems in its habits to be more like the fresh-water swamp mosquito *(A. sylvestris)* in that it breeds more or less in open swamps and continues to appear throughout the season. Control methods of this species partake both of those for the fresh-water swamp mosquito and the woodland-pool mosquito group.

Species Not at Present Economically Important

There are a large number of species of mosquitoes which occur in the state that are not of sufficient importance to merit extended treatment. Yet the writer believes they should be touched upon for sake of completeness. The notices given herewith are taken directly from the New Jersey State Museum issue of 1909 on Insects, prepared by the late Dr. John B. Smith.

Fig. 76. Adult of *Anopheles barberi* Coq. (After John B. Smith).

Anopheles barberi Coq. (The Tree-Hole *Anopheles*). Bordentown, August 14, 16, adults (Brakeley), Chester, September 6-11. This species breeds exclusively in the water in tree-holes and never gets far away from its breeding grounds.

Psorophora ciliata Fabr. (The Fringed-Legged Mosquito). Local throughout the state and rarely common as an adult. This is our largest species and lays its eggs in depressed areas likely to be rain-filled. The larvae develop in these temporary pools and feed upon other mosquito wrigglers. They are the giants of their kind, and if there is not sufficient food for all, they eat each other. Larvae have been found from June to September 25, and adults from July 2 to September 30.

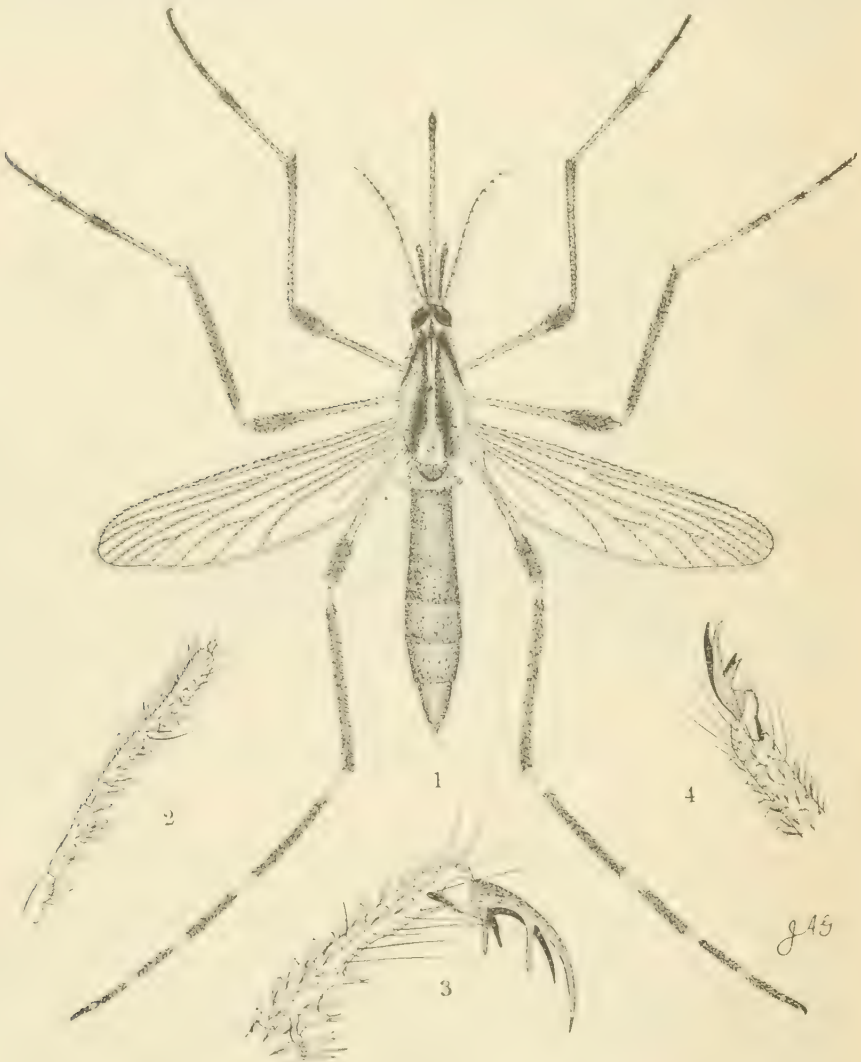

Fig. 77. Adult of *Psorophora ciliata* Fabr. (After John B. Smith).
1, female adult; 2, the palpus; 3, anterior and 4, posterior claws of male (all enlarged).

Psorophora sayi D. & K. (The Big Woods Mosquito). Locally common, chiefly in the northern sections of the state. The larvae breed, as a rule, in heavily shaded woodland pools, and the adults do not leave the vicintiy of

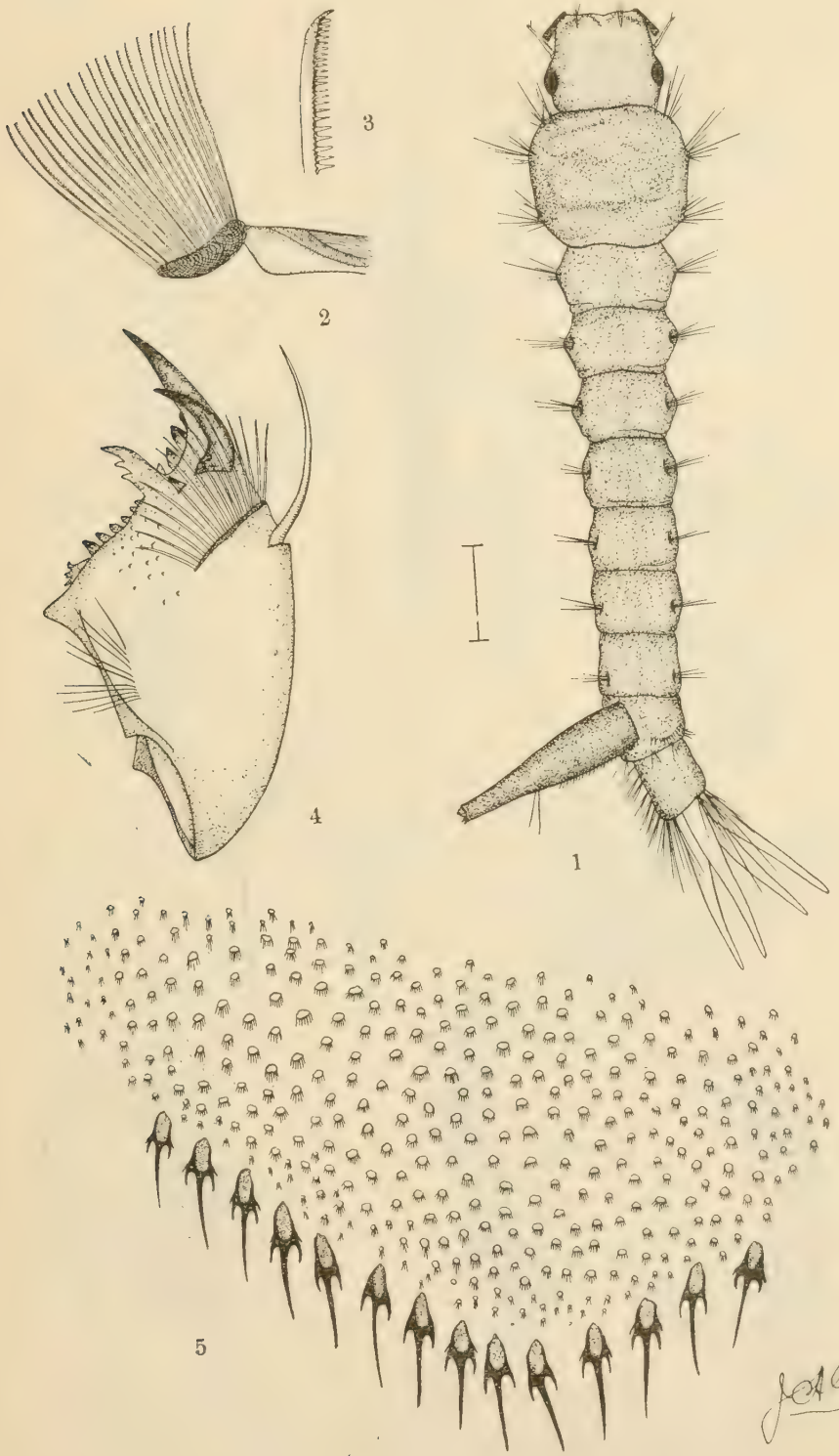

Fig. 78. Larva of *Psorophora ciliata* Fabr. (After John B. Smith).

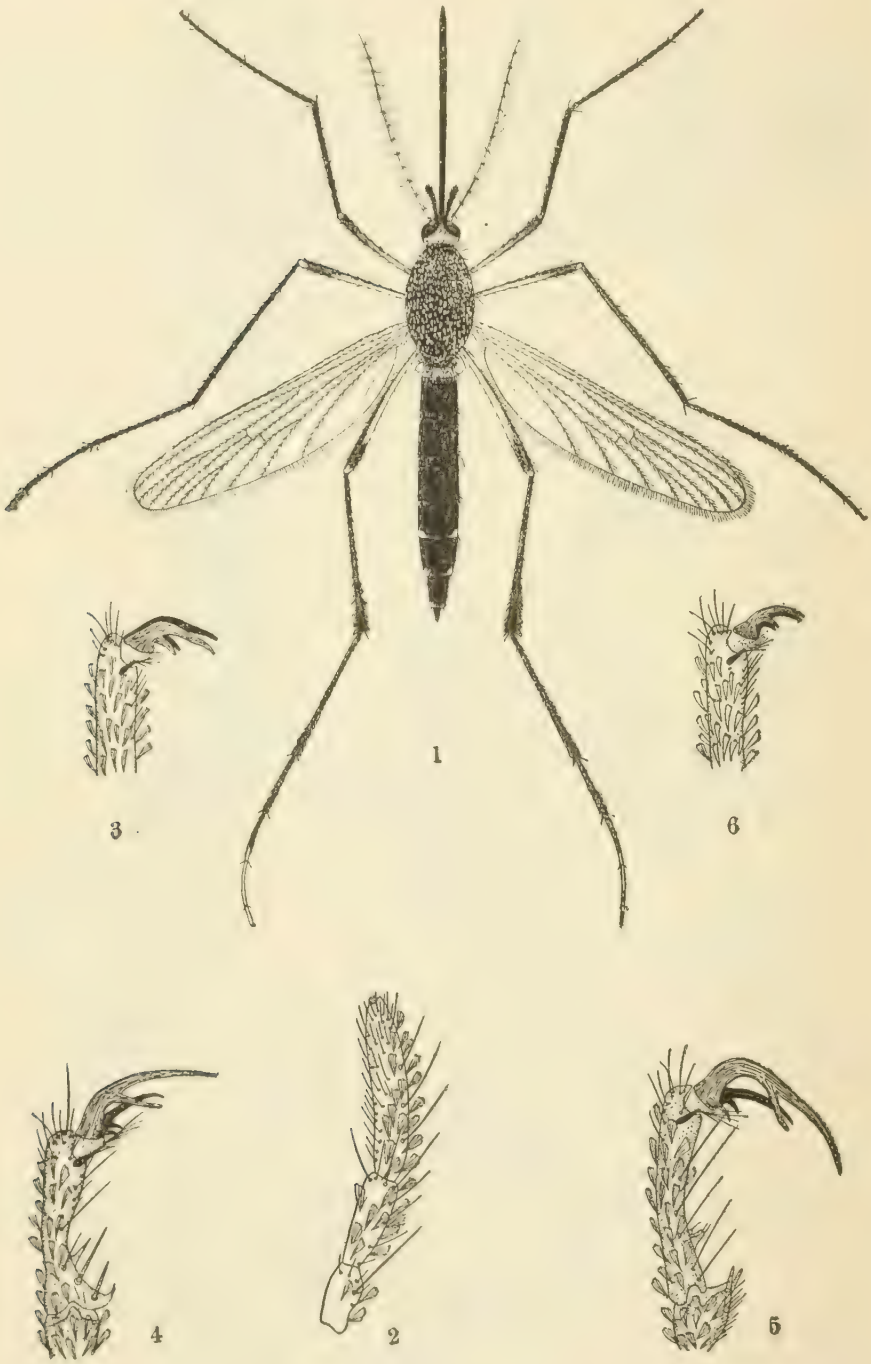

Fig. 79. Adult of *Psorophora sayi* D. & K. (After John B. Smith).
1, female adult; 2, the palpus; 3, anterior claw of female; 4, same of male; 5, middle and 6, posterior claw of male (all enlarged).

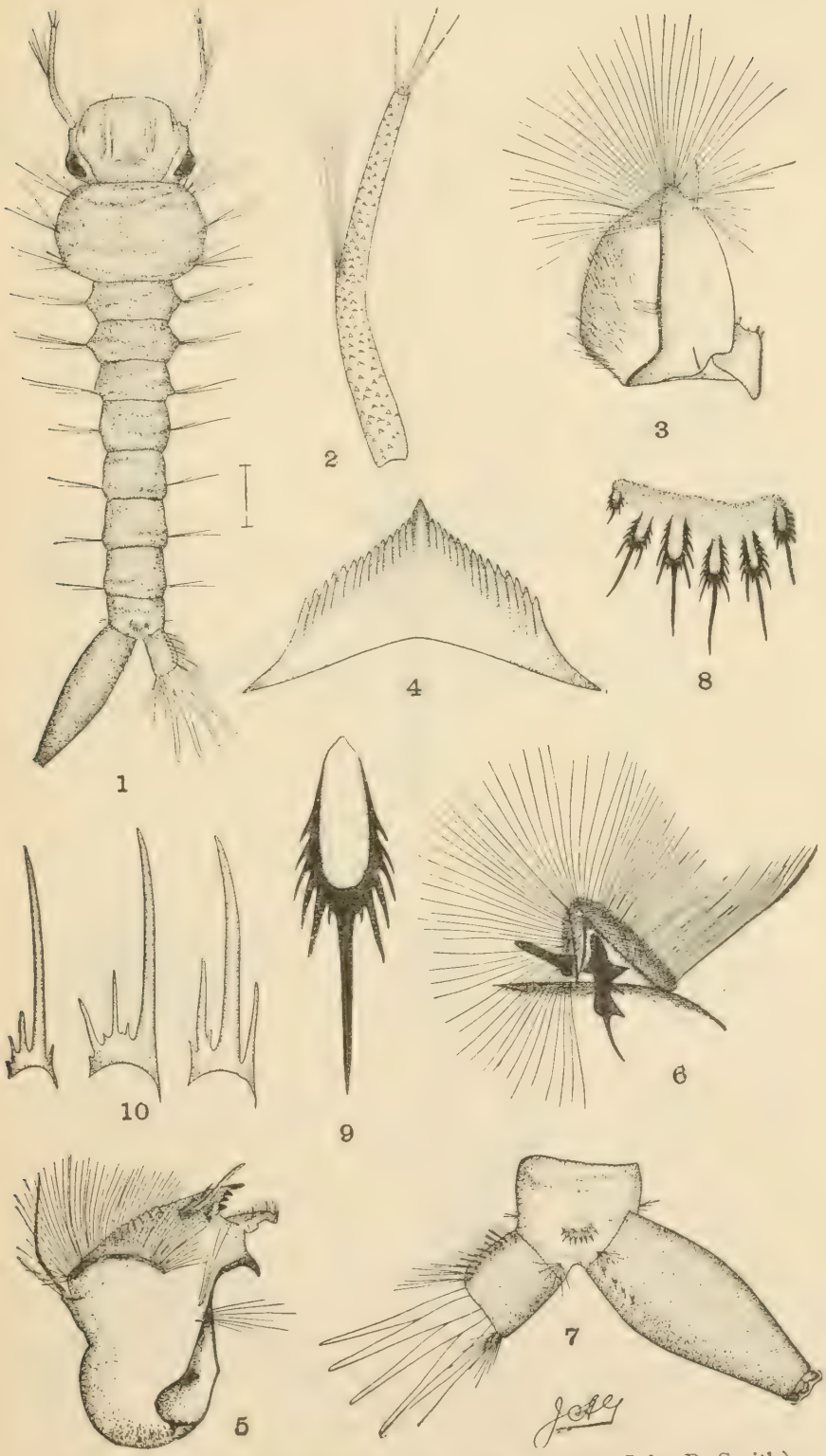

Fig. 80. Larva of *Psorophora sayi* D. & K. (After John B. Smith).

1, larva; 2, its antenna; 3, the maxillary palpus; 4, mentum; 5, mandible; 6, maxillary brush; 7, terminal segments and siphon; 8, the band of scales; 9, an individual scale: 10. siphonal spines (all much enlarged).

their place of birth. They are ferocious biters, and sometimes in the Great Piece meadow region are locally almost unbearable. Larvae have been found only from New Brunswick northward, June to September; adults have been taken also at Spring Lake July 30, and Lakehurst, August 16.

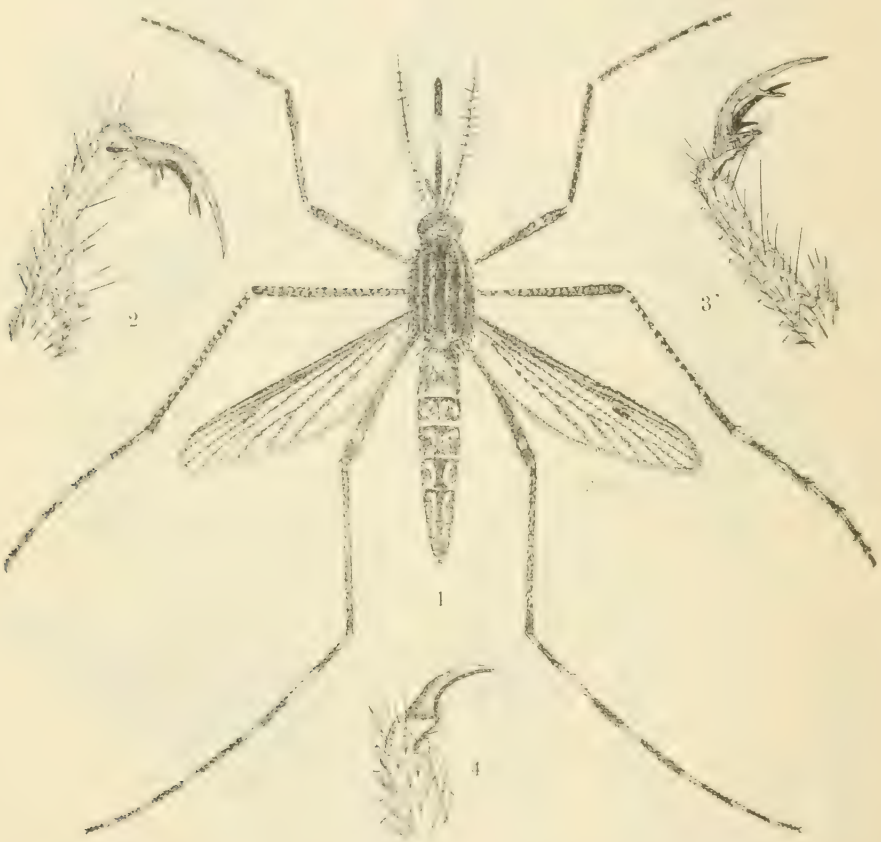

Fig. 81. Adult of *Psorophora columbiae* D. & K. (After John B. Smith).
1, female adult; 2, anterior; 3, middle and 4, posterior claws of male (all enlarged).

Psorophora columbiae D. & K. (The Spotted-Legged Mosquito). Locally common, breeding in open lot pools, though isolated examples of the larvae have been taken in woodland pools. We have only found it at Millburn, Newark, New Brunswick, Delair in July and August; but undoubtedly it is more generally distributed. The adult has never been found attacking man, and though a breeding place is not far from my house, I have never found examples on my porches.

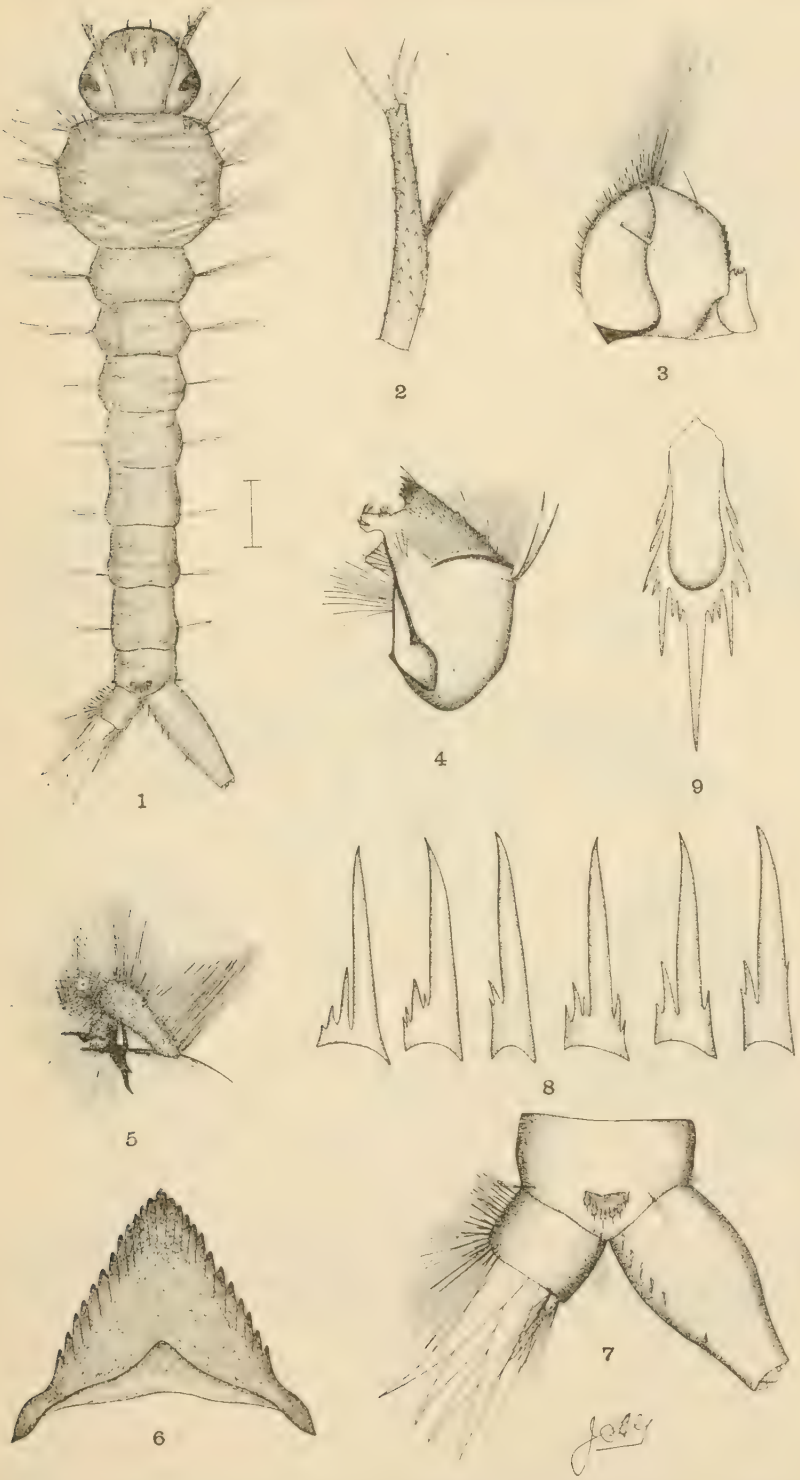

Fig. 82. Larva of *Psorophora columbiae*. (After John B. Smith).

1, larva; 2, its antenna; 3, maxilla; 4, mandible; 5, the mouth brush; 6, mentum; 7, anal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from 8th abdominal segment (all enlarged).

Psorophora discolor Coq. (The Mottled Mosquito). Delair, June 18, July 24, August 15. Larvae have been taken only by Mr. Seal in the one place on the dates mentioned, and we have not found it in any stage elsewhere. It is truly a rare species.

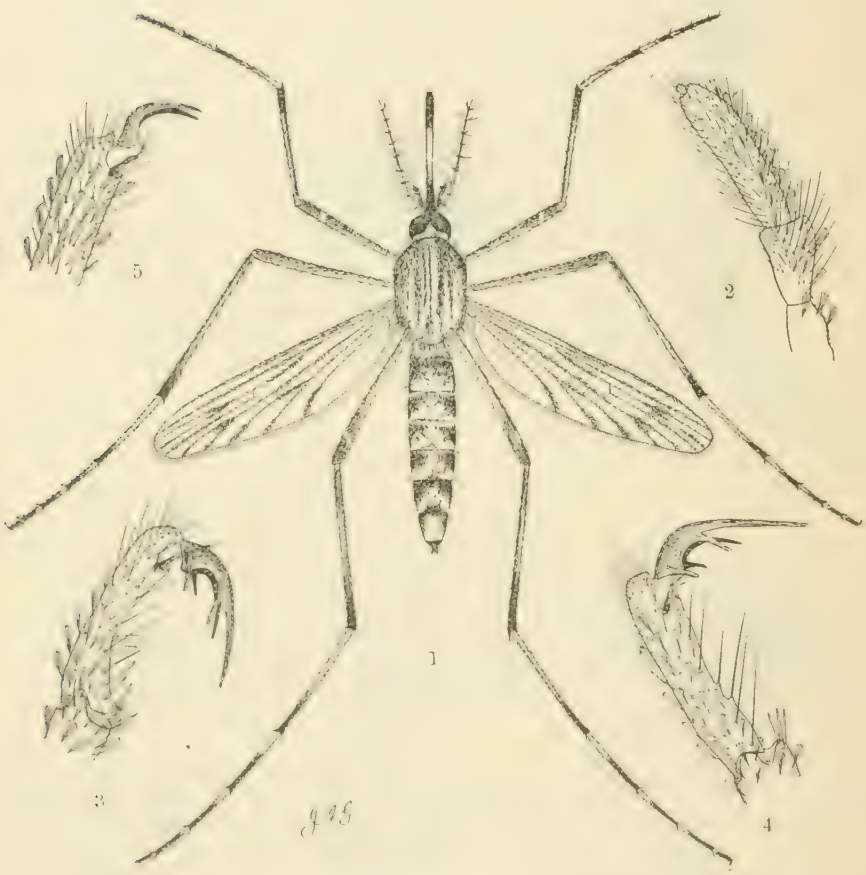

Fig. 83. Adult of *Psorophora discolor* Coq. (After John B. Smith).
1, female adult; 2, its palpus; 3, anterior; 4, middle and 5, posterior claws of the male (all enlarged).

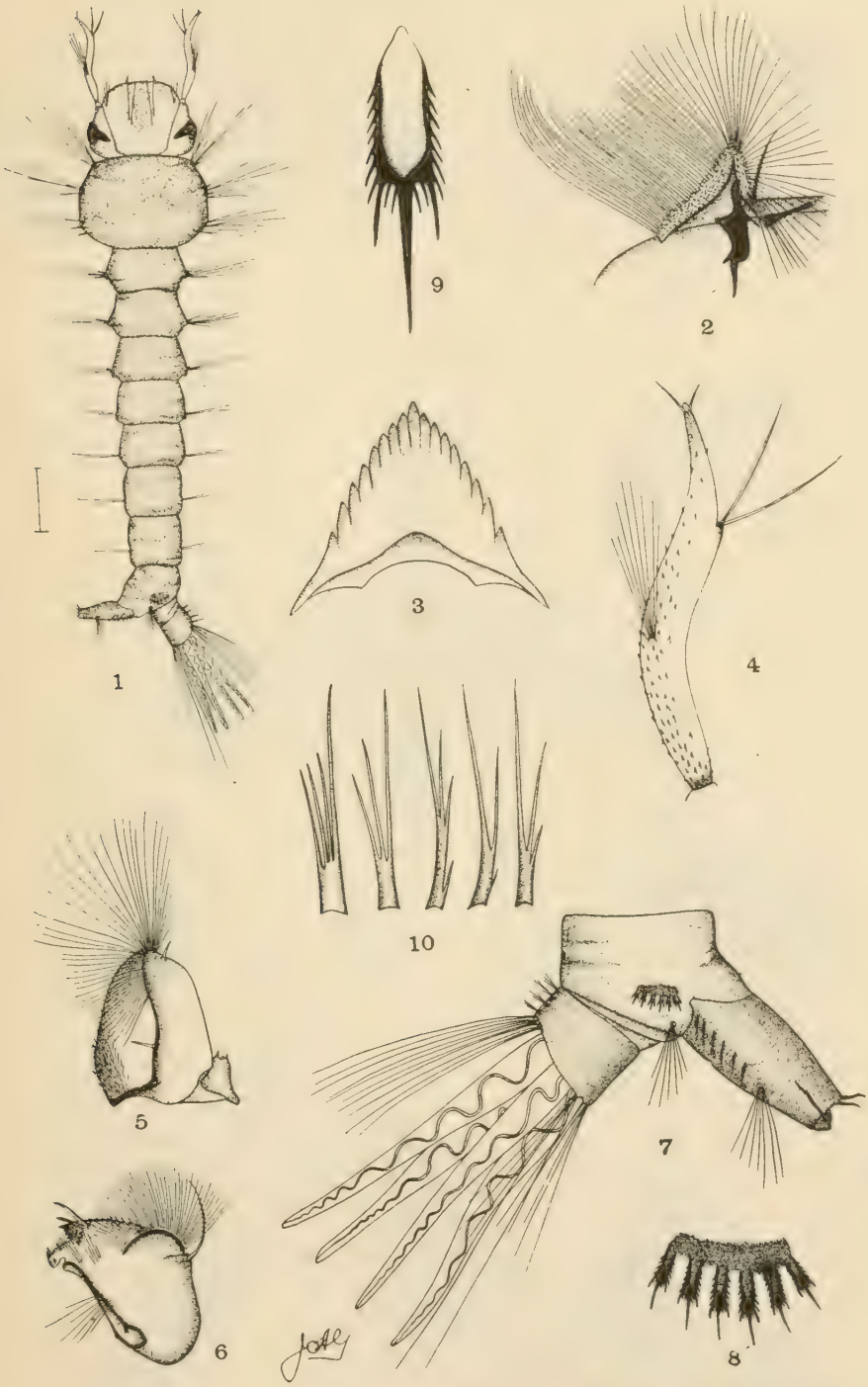

Fig. 84. Larva of *Aedes grossbecki* D. & K. (After John B. Smith).

1, larva; 2, one of the mouth brushes; 3, mentum; 4, antenna; 5, maxillary palpus; 6, mandible; 7, terminal segments with siphon and tracheal gills; 8, scale band of the 8th segment; 9, individual scale; 10 siphonal spines (all enlarged).

Aedes grossbecki D. & K. (The Scaly-Winged Mosquito). Larvae were taken at Paterson in May, at New Brunswick, May and June. Adults were taken also at Westville and Mount Holly, specimens occurring near New Brunswick until July 28. This is a rather rare species, breeding only in pools in dense woodland, whose shelter the adults never leave. There is only a single spring brood, the late captures representing straggling survivors. This species was at first identified with "squamiger," which later proved to be different in habits and early stages.

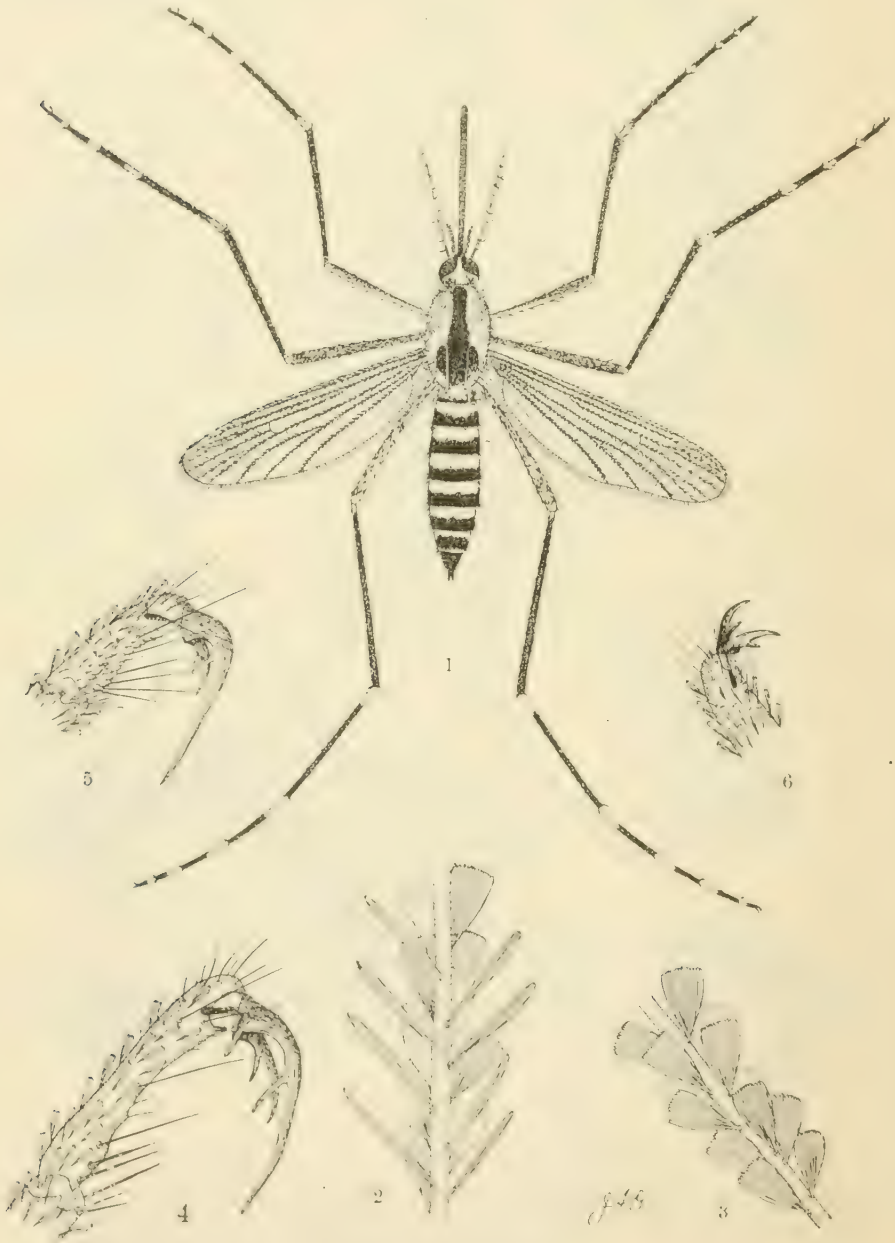

Fig. 85. Adult of *Aedes grossbecki* D. & K. (After John B. Smith).

1, female adult; 2, part of wing vein near outer margin; 3, same near base; 4, anterior; 5, middle and 6, posterior claws of male (all enlarged).

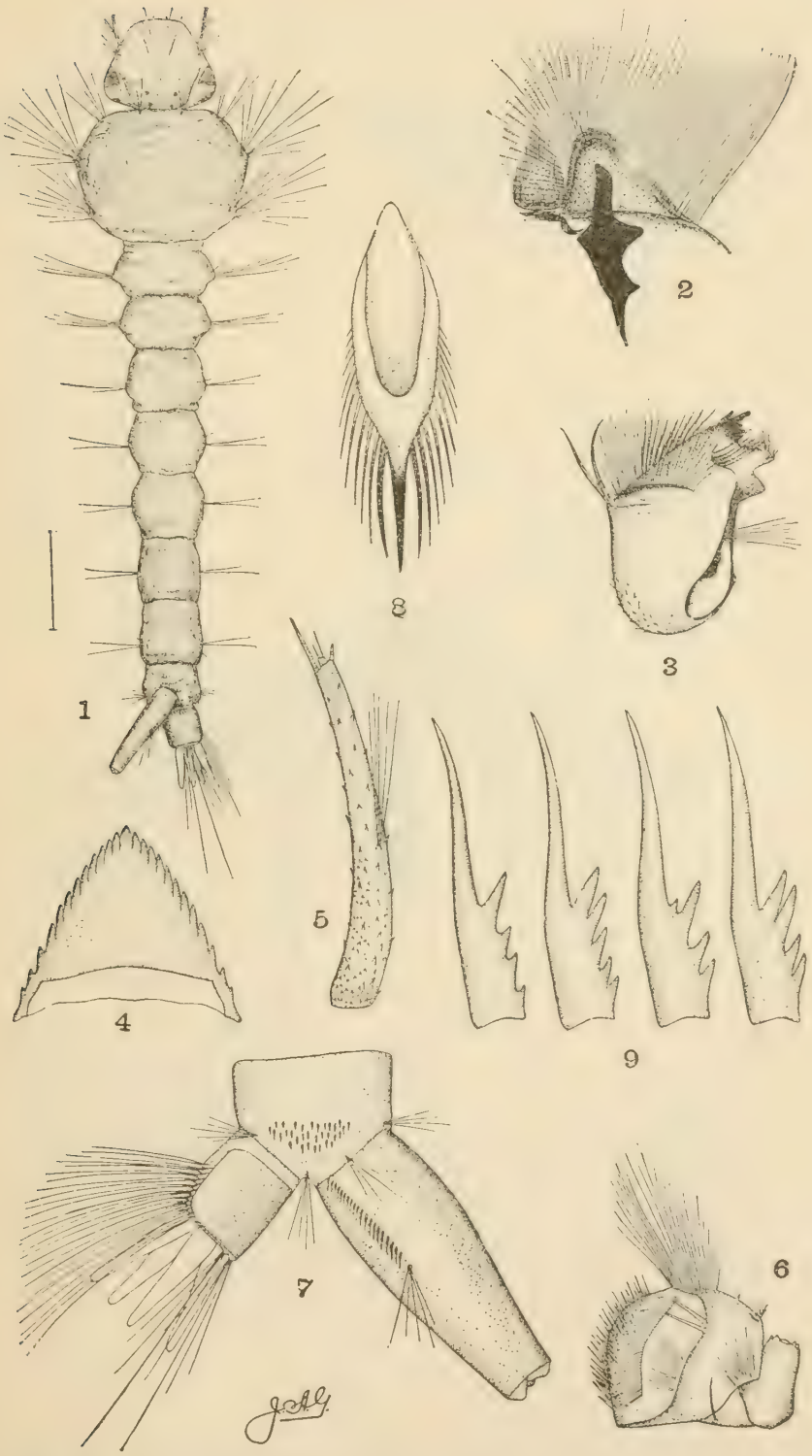

Fig. 86. Larva of *Aedes grossbecki* D. & K. (After John B. Smith).

1, larva; 2, mouth brush; 3, mandible; 4, mentum; 5, antenna; 6, maxilla; 7, terminal segments with siphon; 8, a single scale of the 8th segment; 9, siphonal spines, showing variation (all much enlarged).

A. niveitarsis. (*A. canadensis* Theob). (*The Woodland-Pool Mosquito*). Larvae were found near Paterson May 9, 14, in a rocky, mountain pool, and the adults bred from them are the types of the species, no other examples of which have been taken since.

Fig. 87. Adult of *Aedes niveitarsis.* (*A. canadensis* Theob). (After John B. Smith).

A. fitchii Felt. Very much like *A. abfitchii* in appearance and probably in habit; but rare in New Jersey. Mr. Brakeley has taken larvae at Lahaway and Mr. Grossbeck in the Great Piece Meadows, both in April.

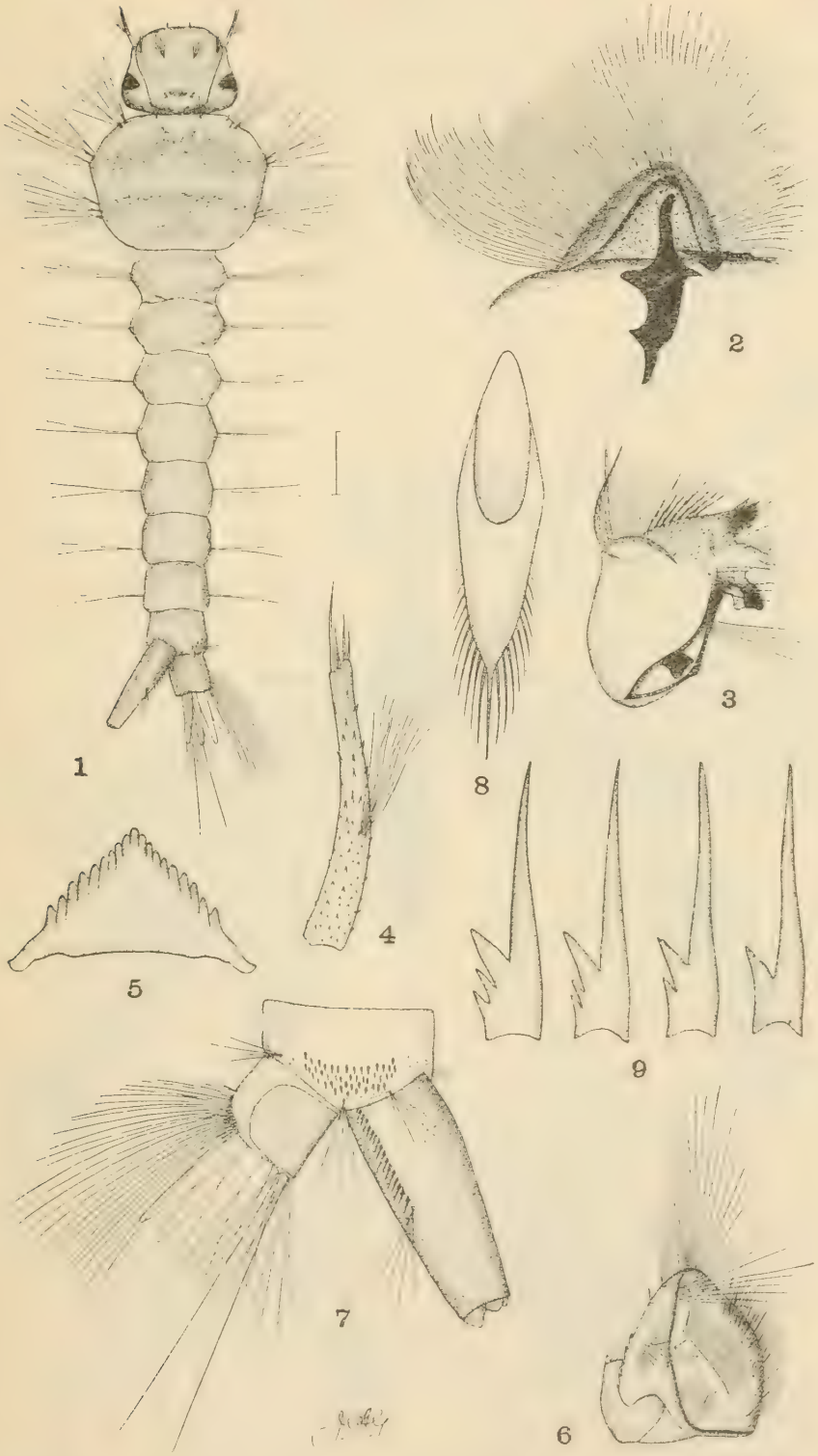

Fig. 88. Larva of *Aedes nivcitarsis*. *A. canadensis* Theob. (After John B. Smith).

1, larva; 2, mouth brush; 3, mandible; 4, antenna; 5, mentum; 6, maxilla; 7, terminal segments with siphon; 8, a single scale from the 8th segment; 9, siphonal spines showing variation (all much enlarged).

Orthopodomyia signifer Coq. (The White-Lined Mosquito). Larvae have been taken at Chester, August 5, November 17; Riverton, August 8; Delair, August 20; Lahaway, August. This species breeds normally in tree holes, though occasionally it resorts to barrels or old tubs; it has only been taken in late fall.

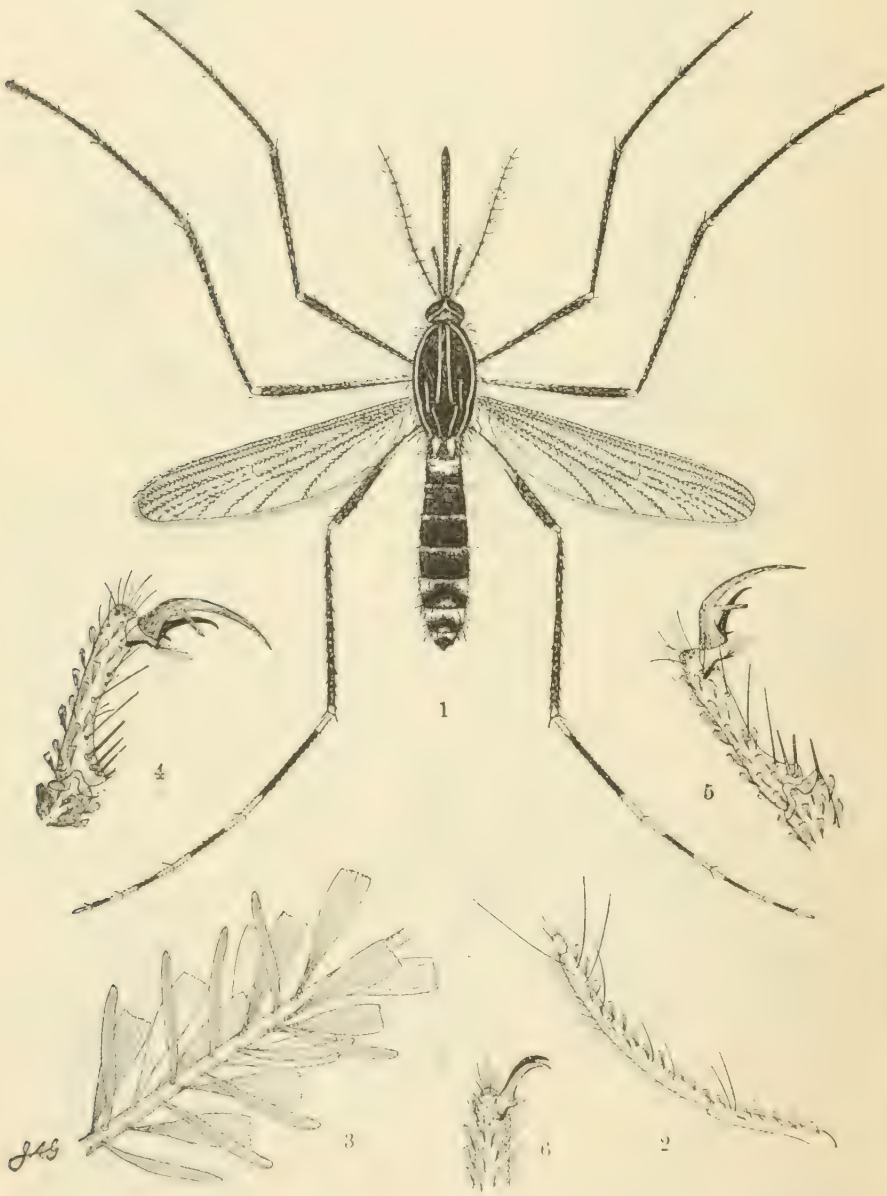

Fig. 89. Adult of *Orthopodomyia signifer* Coq. (After John B. Smith).
1, female adult; 2, palpus; 3, part of the wing-vein showing scales; 4, anterior; 5, middle and 6, posterior claws of male (all much enlarged).

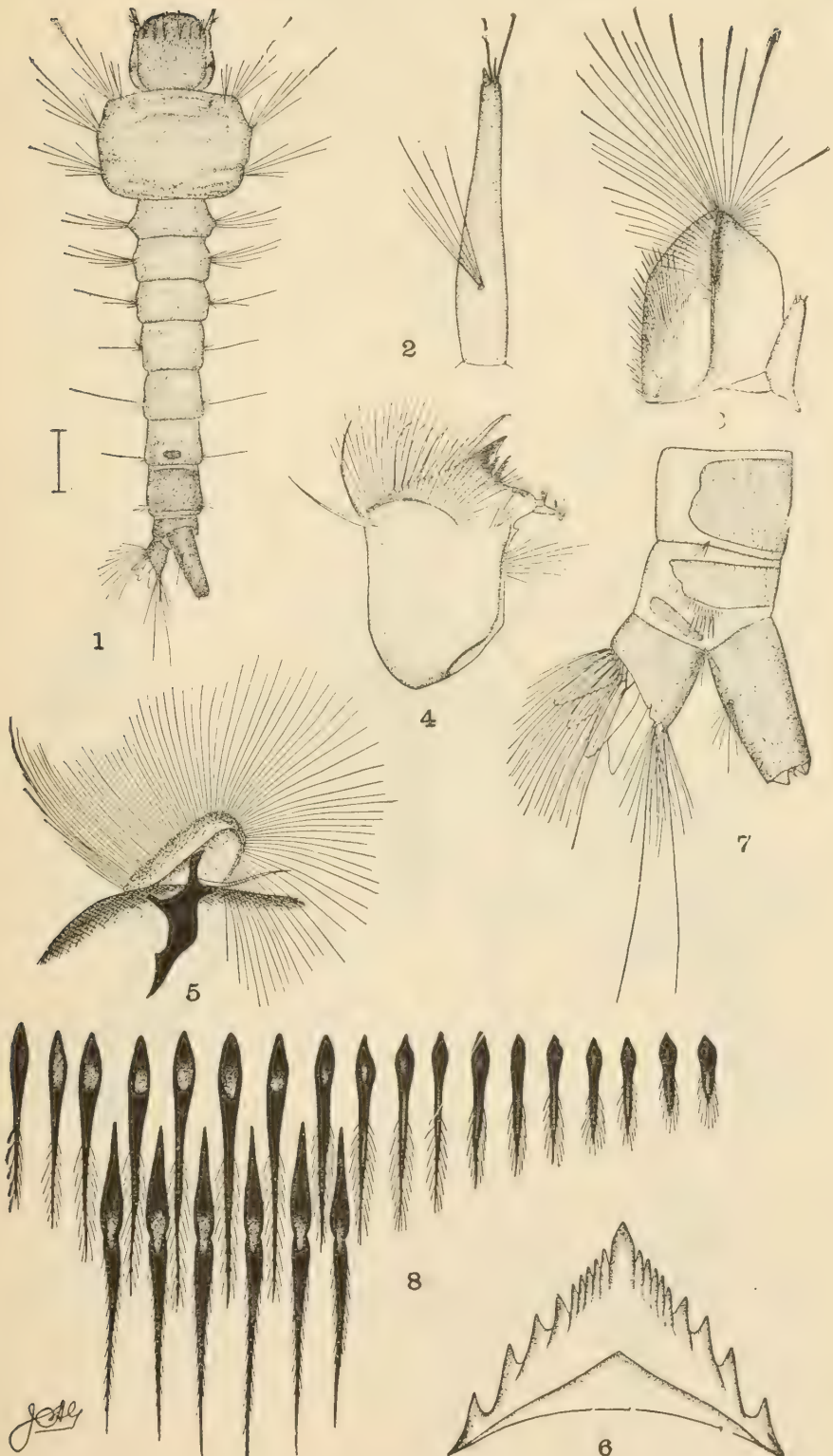

Fig. 90. Larva of *Orthopodomyia signifer* Coq. (After John B. Smith).

1, larva; 2, antenna; 3, palpus; 4, mandible; 5, mouth brush; 6, mentum; 7, terminal segments, showing dorsal plates and siphon; 8, the scale patch of the 8th segment (all much enlarged).

A. atropalpus Coq. (The Rock-Pool Mosquito). This species breeds only in rock-pools. It has been taken in Maine and Maryland, but not yet in New Jersey. It is almost certain that it occurs along the shores of the Delaware River near the Water Gap.

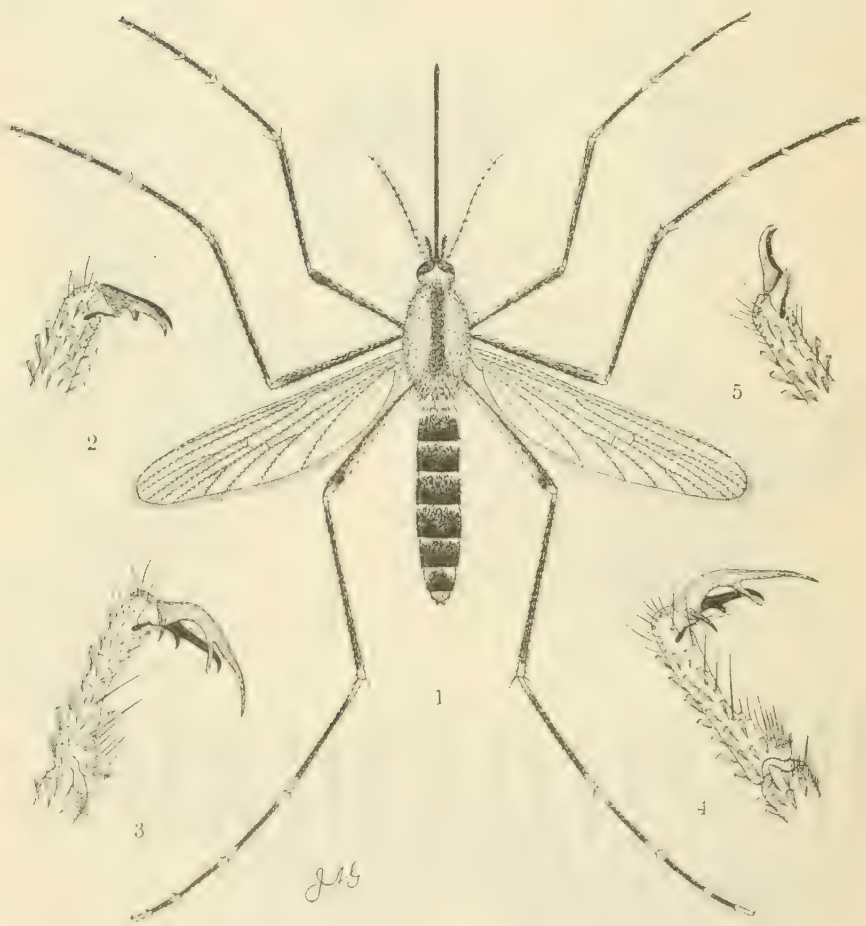

Fig. 91. Adult of *Aedes atropalpus* Coq. (After John B. Smith).

1, female adult; 2, anterior claw of same; 3, anterior; 4, middle and 5, posterior claws of male (all much enlarged).

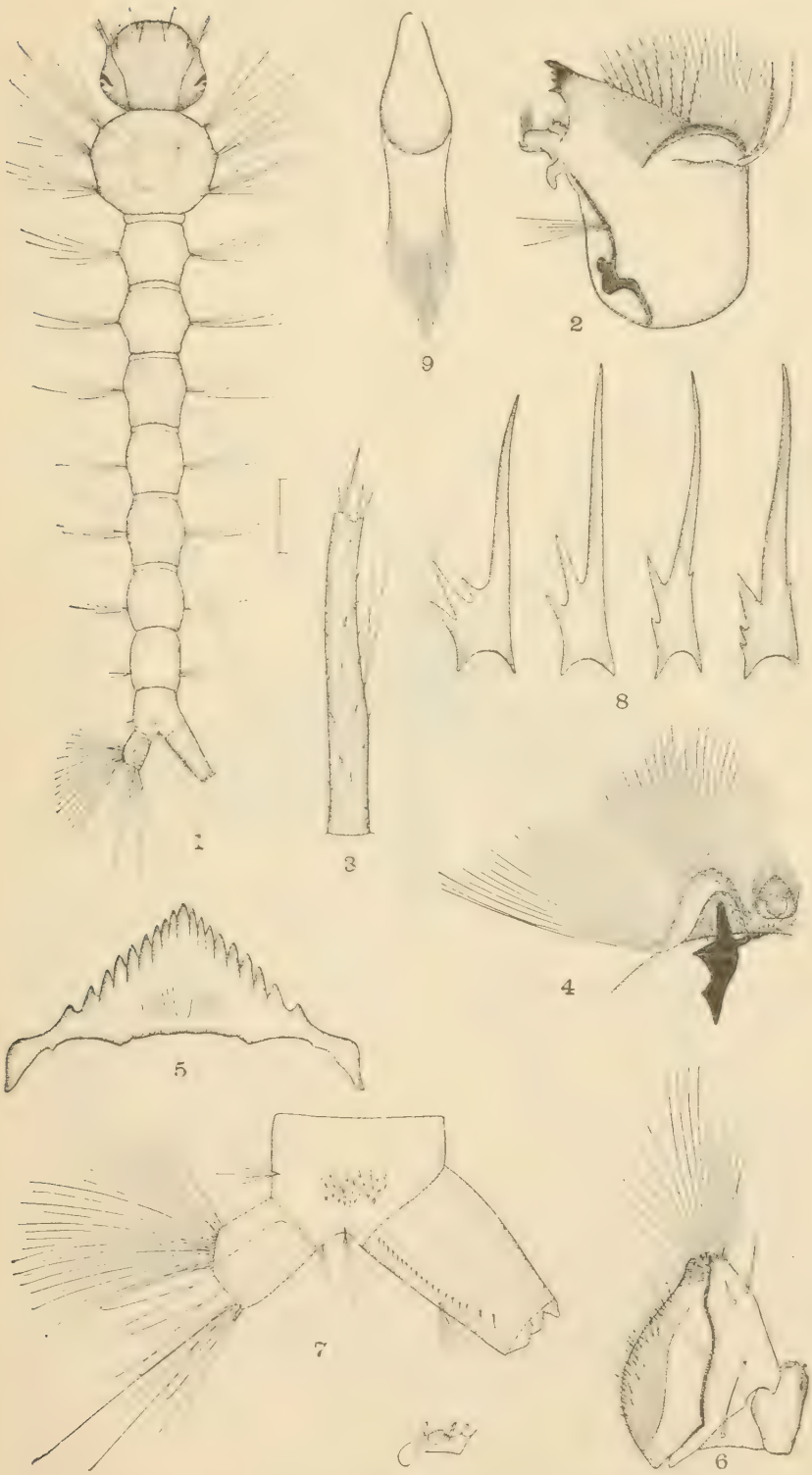

Fig. 92. Larva of *Aedes atropalpus* Coq. (After John B. Smith).

1, larva; 2, mandible; 3, antenna; 4, mouth brush; 5, mentum; 6, maxillary palpus; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from the 8th segment (all much enlarged).

Culex dyari Coq. Culver's Lake, May 29, bred from pupa.

Fig. 93. Adult of *Culex dyari* Coq. (After John B. Smith).

A. triseriatus Say. (The Tree-Hole Mosquito). Taken in many localities in the northern half of the state; but undoubtedly occurs everywhere in it. Breeds normally in tree holes; but also occasionally in pails or other wooden receptacles. Larvae have been found as early as April 18 (Paterson), as late as November 17 (Chester), and at all periods throughout the summer.

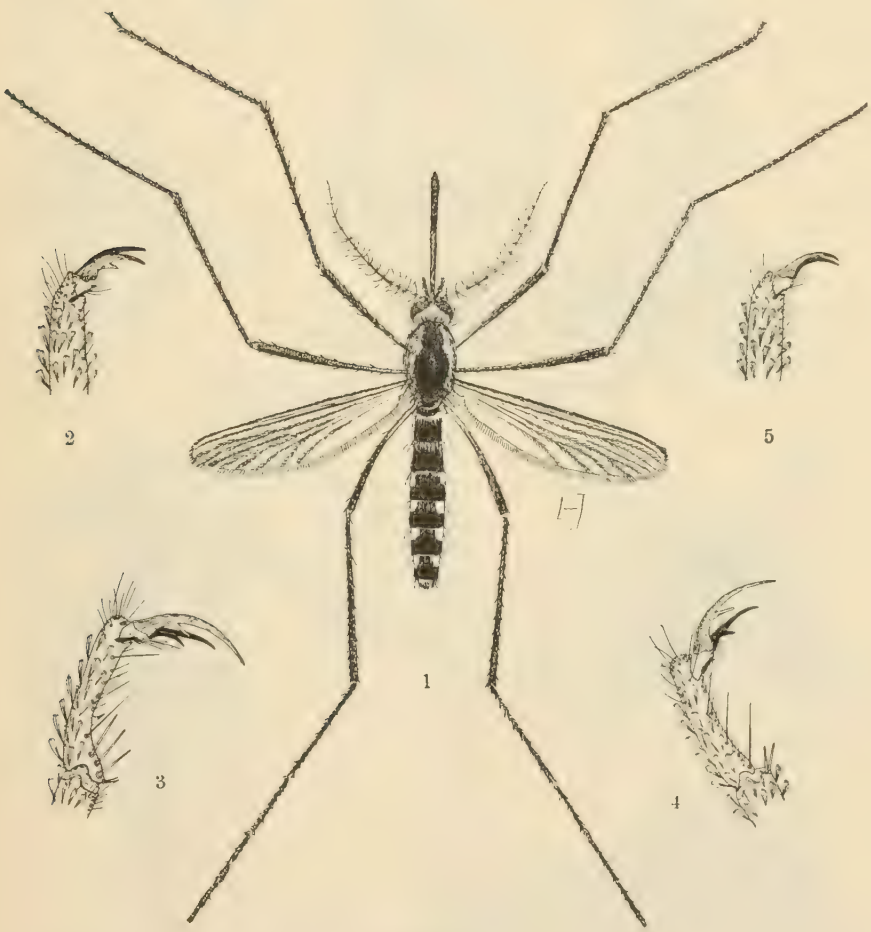

Fig. 94. Adult of *Aedes triseriatus* Say. (After John B. Smith).

1, female adult; 2, anterior claws of same; 3, anterior; 4, middle and 5, posterior claws of male (all enlarged).

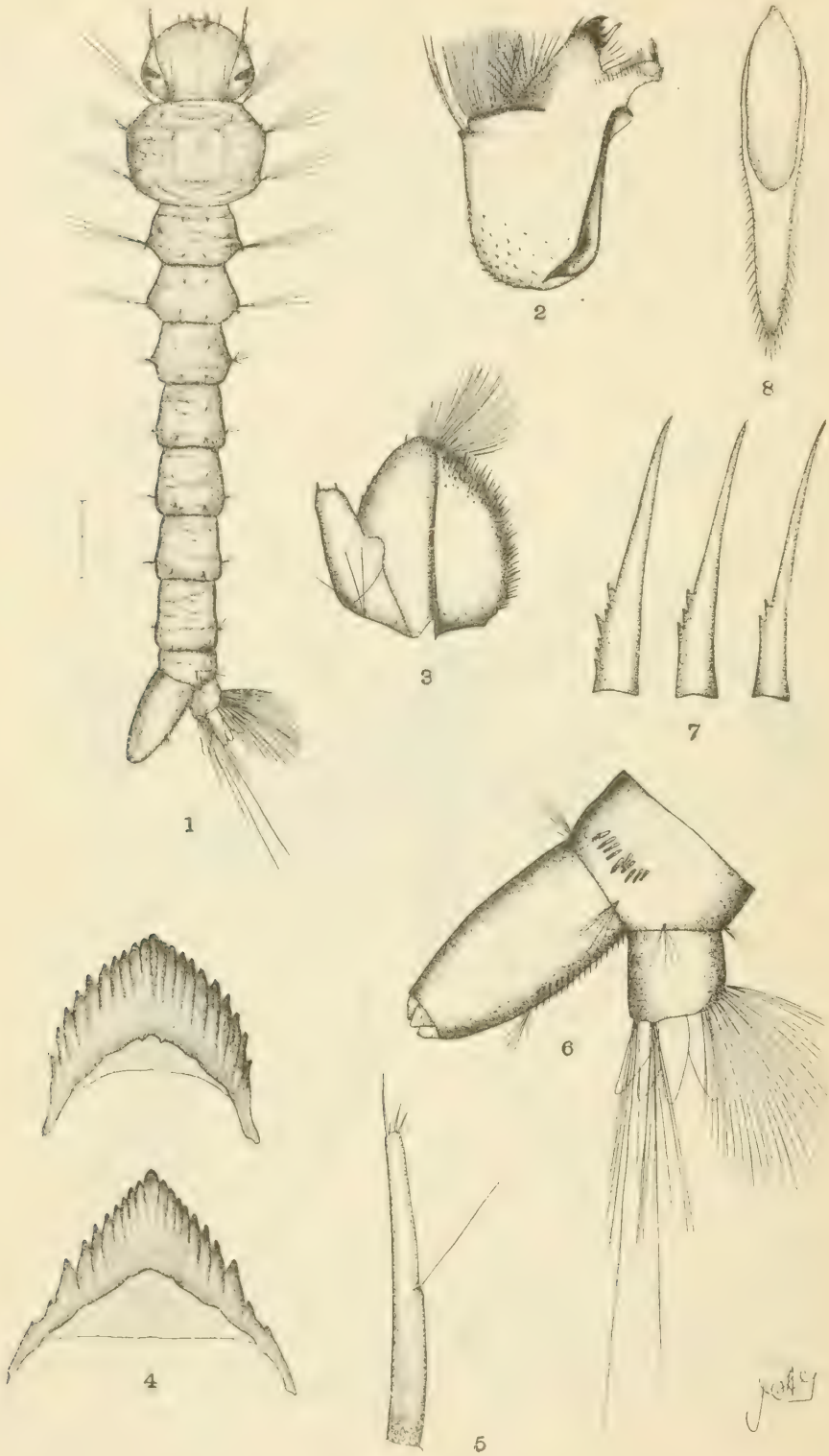

Fig. 95. Adult of *Aedes triseriatus* Say. (After John B. Smith).

1, larva; 2, mandible; 3, maxillary palpus; 4, variations of mentum; 5, antenna; 6, terminal segments and siphon; 7, siphonal spines; 8, a single scale of the 8th segment (all much enlarged).

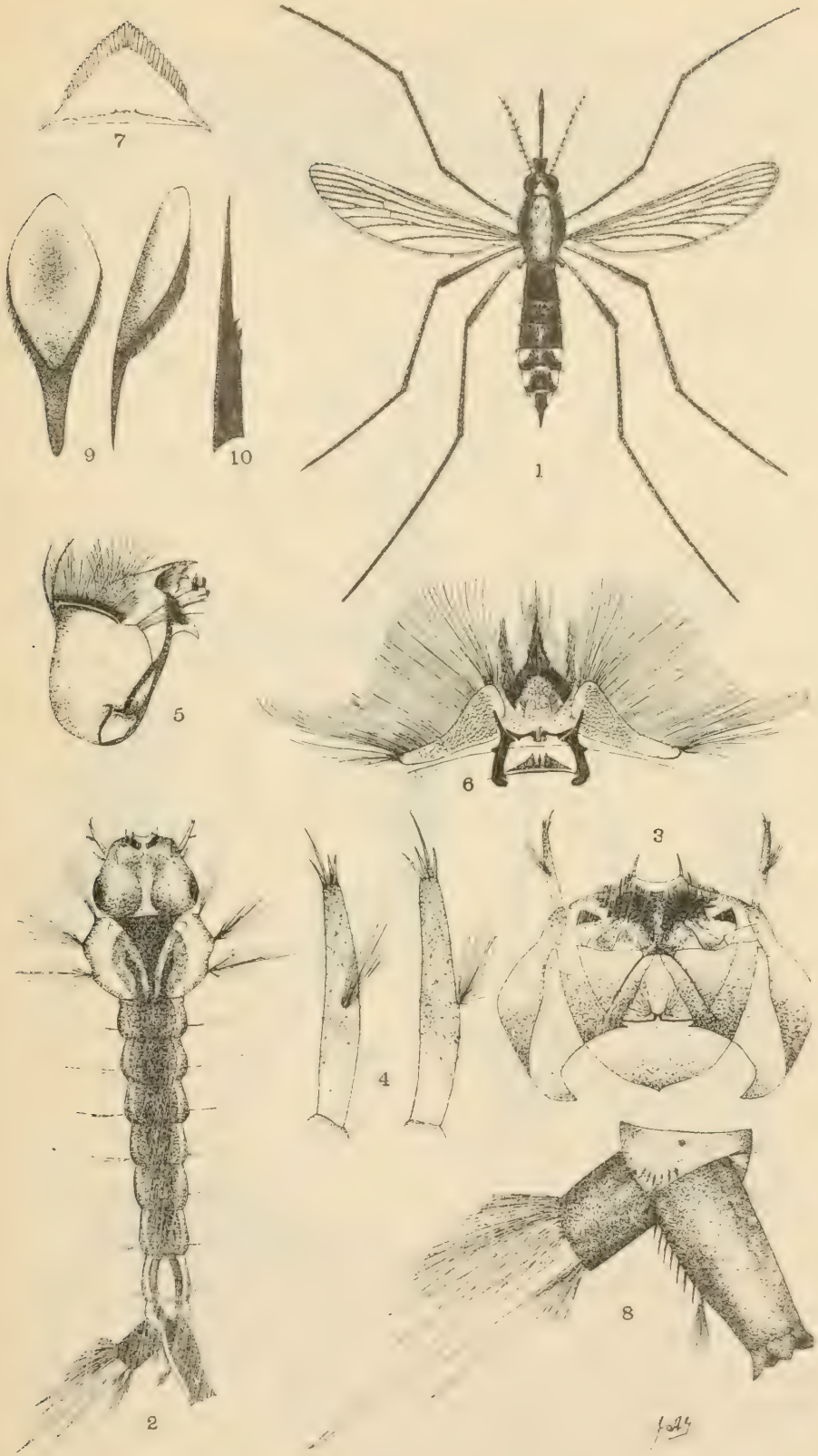

Fig. 96. Adult and larva of *Aedes altanticus* D. & K. (After John B. Smith).

1, female adult; 2, larva; 3, larval head from beneath; 4, antennae; 5, mandible; 6, mouth brushes; 7, mentum; 8, terminal segments with siphon; 9, scales of 8th segment from below and side; 10 siphonal spine (all enlarged).

A. atlanticus D. & K. (The Silver-Striped Mosquito). Breeds in low, swampy woodland, and sometimes in mountain pools. Adults have been taken at Great Piece meadow, August 17; New Brunswick, June 23, September 5; Cape May, August 21. Larvae have been found at Great Piece meadow, August 9; Orange mountains, July 6; New Brunswick, 28, August 13, September 3, 30.

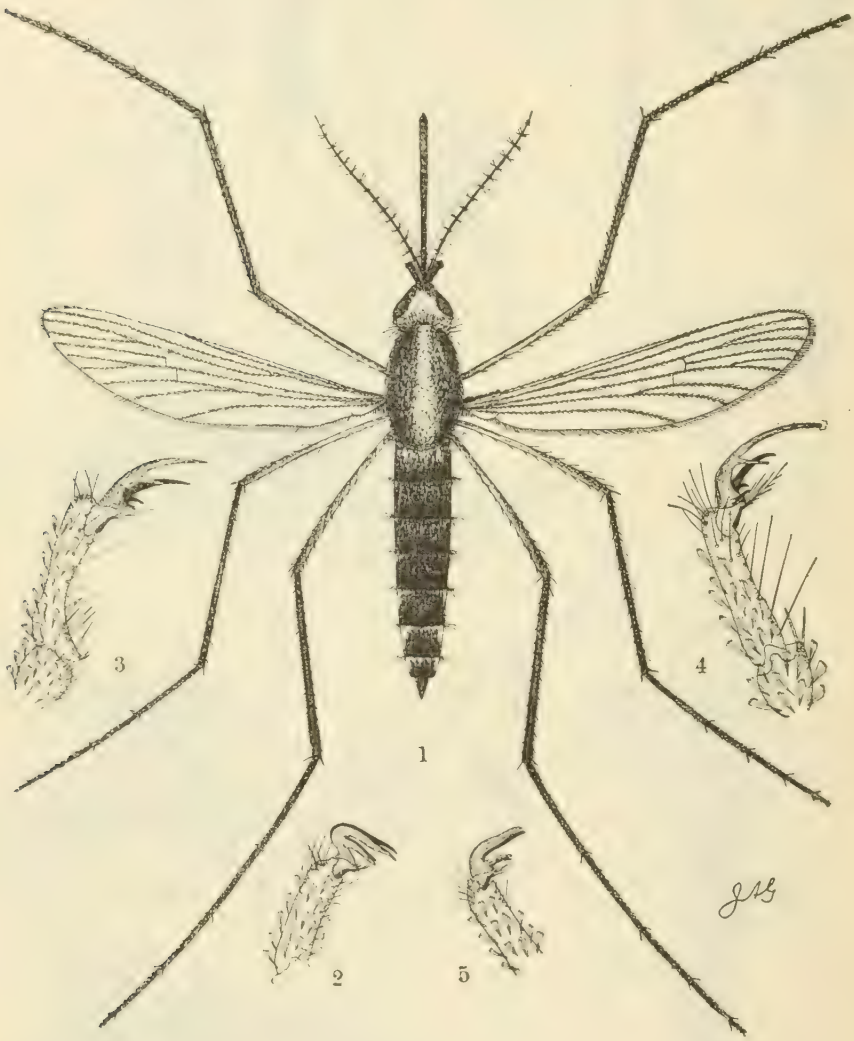

Fig. 97. Adult of *Aedes dupreei* Coq. (After John B. Smith).
1, adult female; 2, anterior claw of same; 3, anterior; 4, middle and 5, posterior claws of male (all much enlarged).

A. dupreei Coq. (Dupree's Mosquito). Occurs in the same pools with the preceding and at the same time. It is a small, rare species; the adult does not bite humans and the larva is a bottom feeder that gets its supply of oxygen from the water itself.

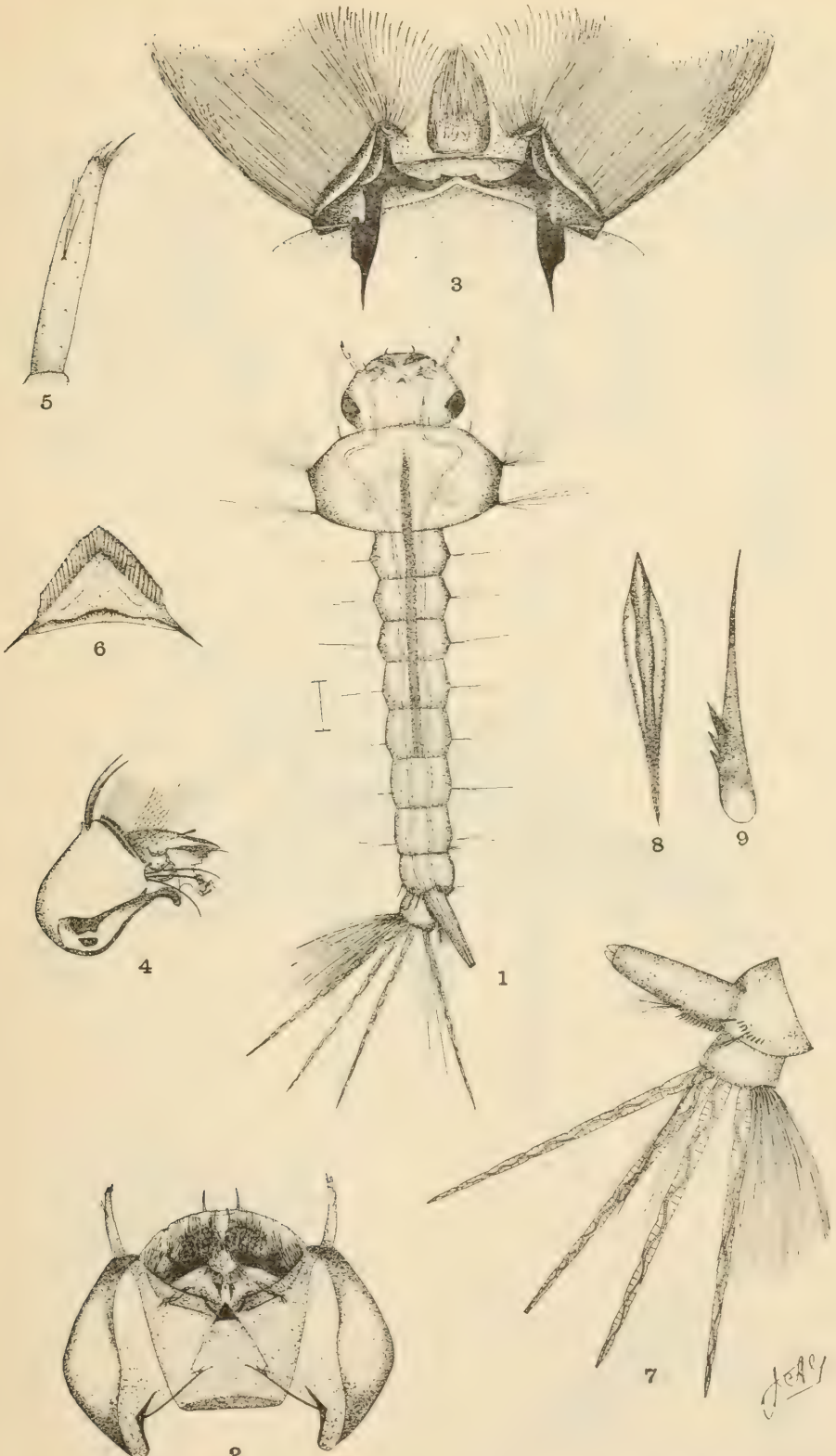

Fig. 98. Larva of *Aedes dupreci* Coq. (After John B. Smith).

1, larva; 2, head from beneath; 3, mouth brushes; 4, mandible; 5, antenna; 6, mentum; 7, terminal segments, showing siphon and tracheal gills; 8, scale of the 8th segment; 9, a siphonal spine (all much enlarged).

A. abserratus Felt. (The Unbanded-Legged Mosquito). Larvae have been taken in the Orange mountains, April 20, and at New Brunswick, April 16 to May 2. It is probably the earliest of the spring species to mature, the larvae rarely extending into May, and not appearing again later in the season. Breeds in low, swampy woodlands and in mountain pools.

Fig. 99. Adult of *Aedes abserratus* Felt. (After John B. Smith).

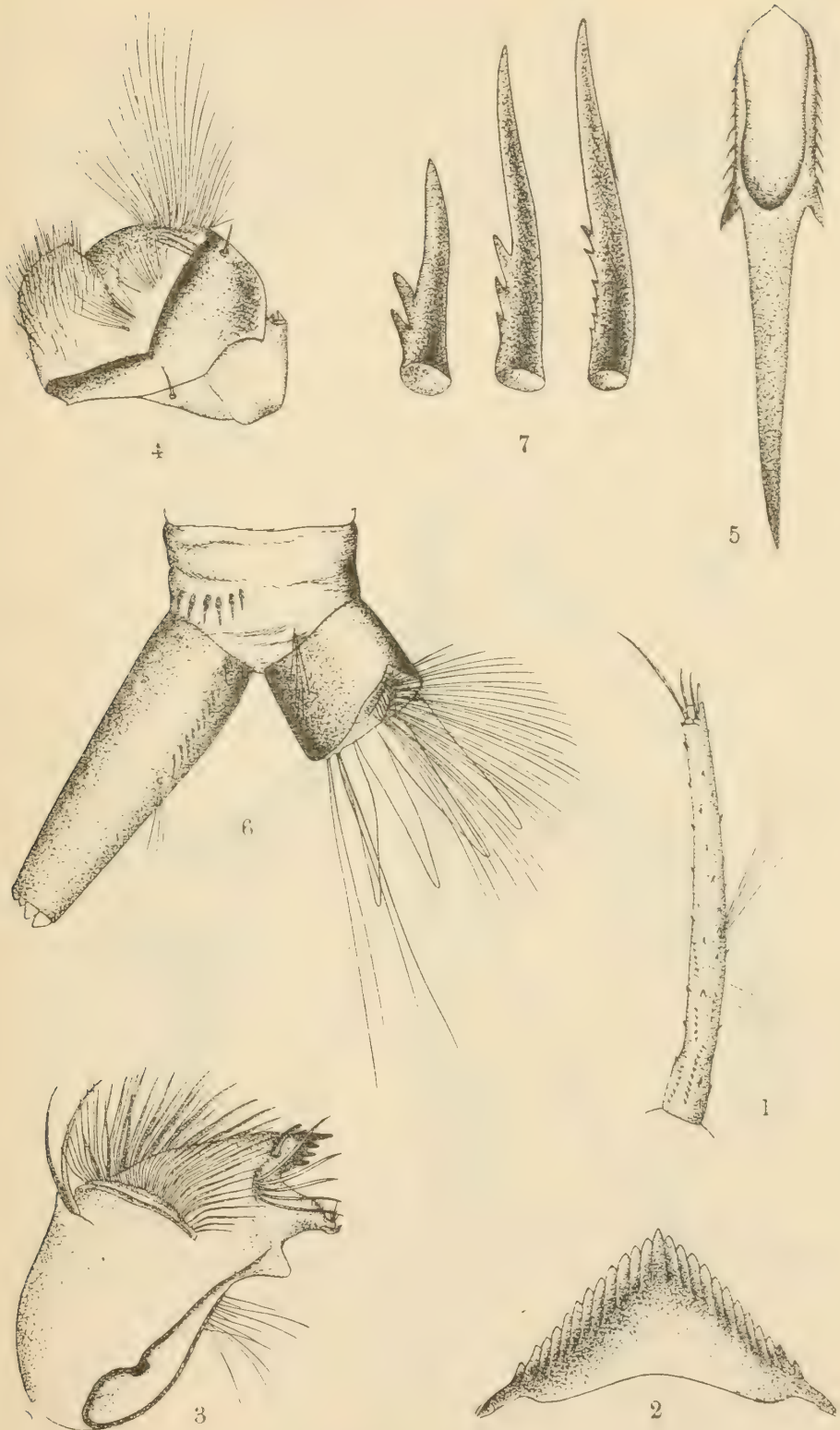

Fig. 100. Larva of *Aedes abserratus* Felt. (After John B. Smith).

1, antenna; 2, mentum; 3, mandible; 4, palpus; 5, scale from 8th segment; 6, terminal segments with siphon; 7, siphonal spines (all enlarged).

A. trivittatus Coq. (The Three-Striped Mosquito). Quite generally distributed throughout the state; hardly common, but more abundant in the northern half. Larvae from May 8 to August 12; adults from July 2 to September 2. Breed in unsheltered pools, associated with *"sylvestris."*

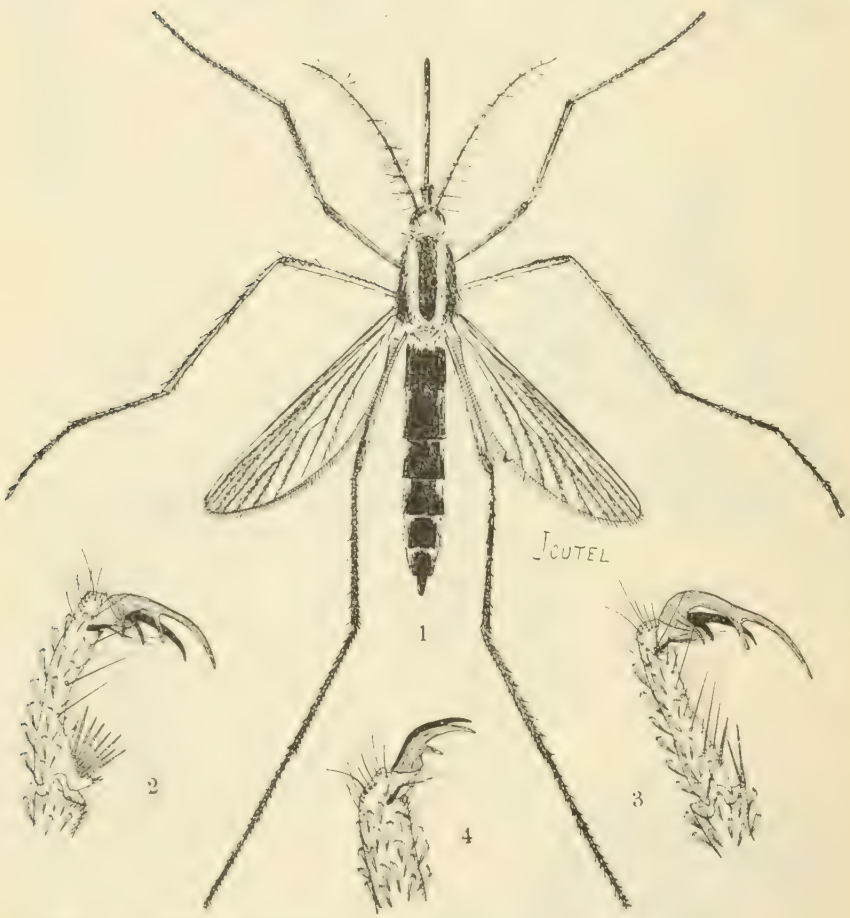

Fig. 101. Adult of *Aedes trivittatus* Coq. (After John B. Smith). 1, adult female; 2, anterior; 3, middle and 4, posterior claws of male (all much enlarged).

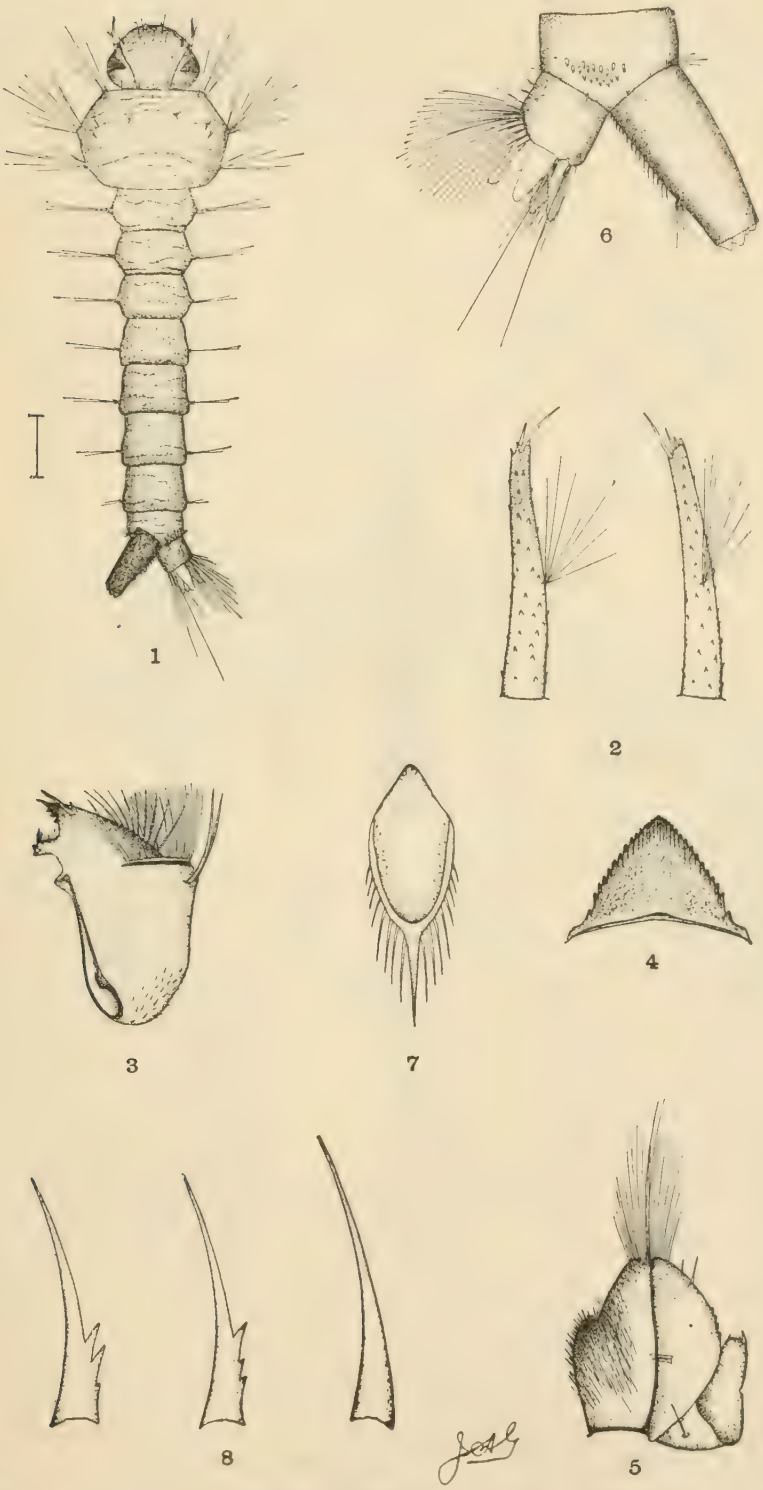

Fig. 102. Larva of *Aedes trivittatus* Coq. (After John B. Smith).

1, larva; 2, antennae; 3, mandible; 4, mentum; 5, maxillary palpus; 6, terminal segments and siphon; 7, a single scale of 8th segment; 8, siphonal spines showing variation (all enlarged).

A. hirsuteron Theob. (The Brown-Striped Mosquito). Larvae in the Great Piece meadow, April 19 to May 10; adults Chester, July 30, September 10; Great Piece meadow, September 13; Lake Hopatcong, July 21; Trenton, July 18. Mr. Grossbeck writes, "Taken rarely except in the Great Piece meadows, where in some years it occurs in countless millions."

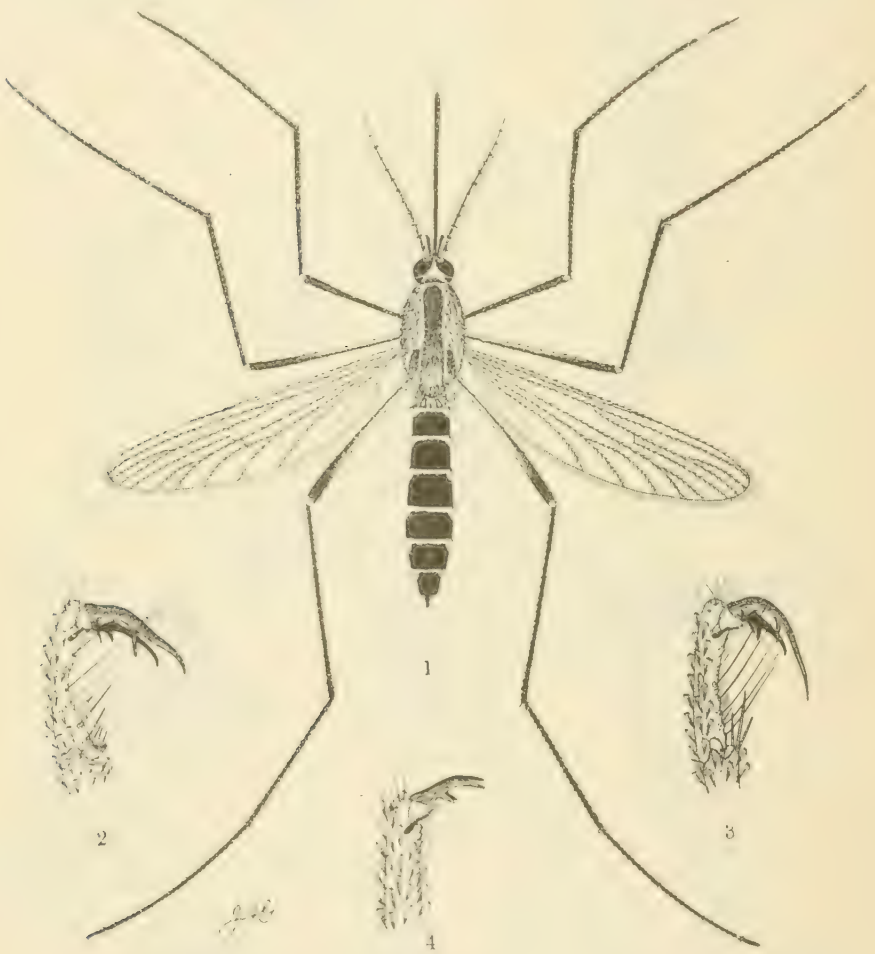

Fig. 103. Adult of *Aedes hirsuteron* Theob. (After John B. Smith).
1, female adult; 2, anterior; 3, middle and 4, posterior claws of male (all enlarged).

A. inconspicuous Gross (The Inconspicuous Mosquito), classified as a form of *A. trivittatus* Coq. Larvae taken on Garrett mountain, Paterson, September 29, which produced adults October 4, 5. They were found in a rock-pool, and have not been found since.

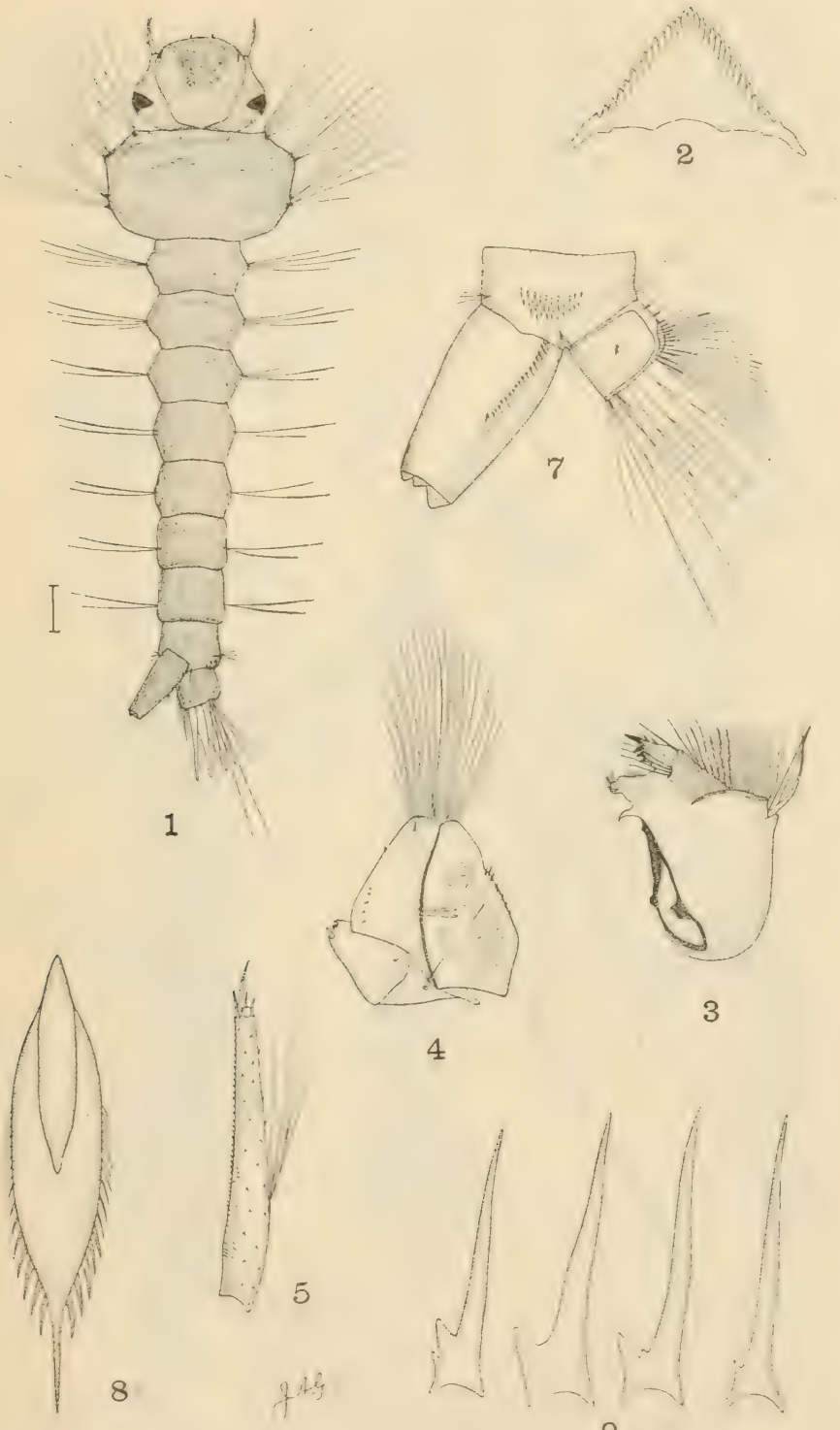

Fig. 104. Larva of *Aedes hirsuteron* Theob. (After John B. Smith).

1, larva; 2, mentum; 3, mandible; 4, maxillary palpus; 5, antenna; 7, terminal segments and siphon; 8, a scale from the 8th segment; 9, siphonal spines, showing variation (all much enlarged).

A. aurifer Coq. (The Golden-Scale Mosquito). Larvae from March 23 to May 10 at Lahaway; Arlington, May 9; Great Piece meadows, May. Adults from early May to late August, the specimens matured in May living throughout the summer and biting fiercely whenever they got a chance. They have been found in troublesome numbers at Lake Hopatcong, Springdale, Culver's Lake and Swartswood Lake. Breeds in woodland pools, the larger and more permanent being preferred.

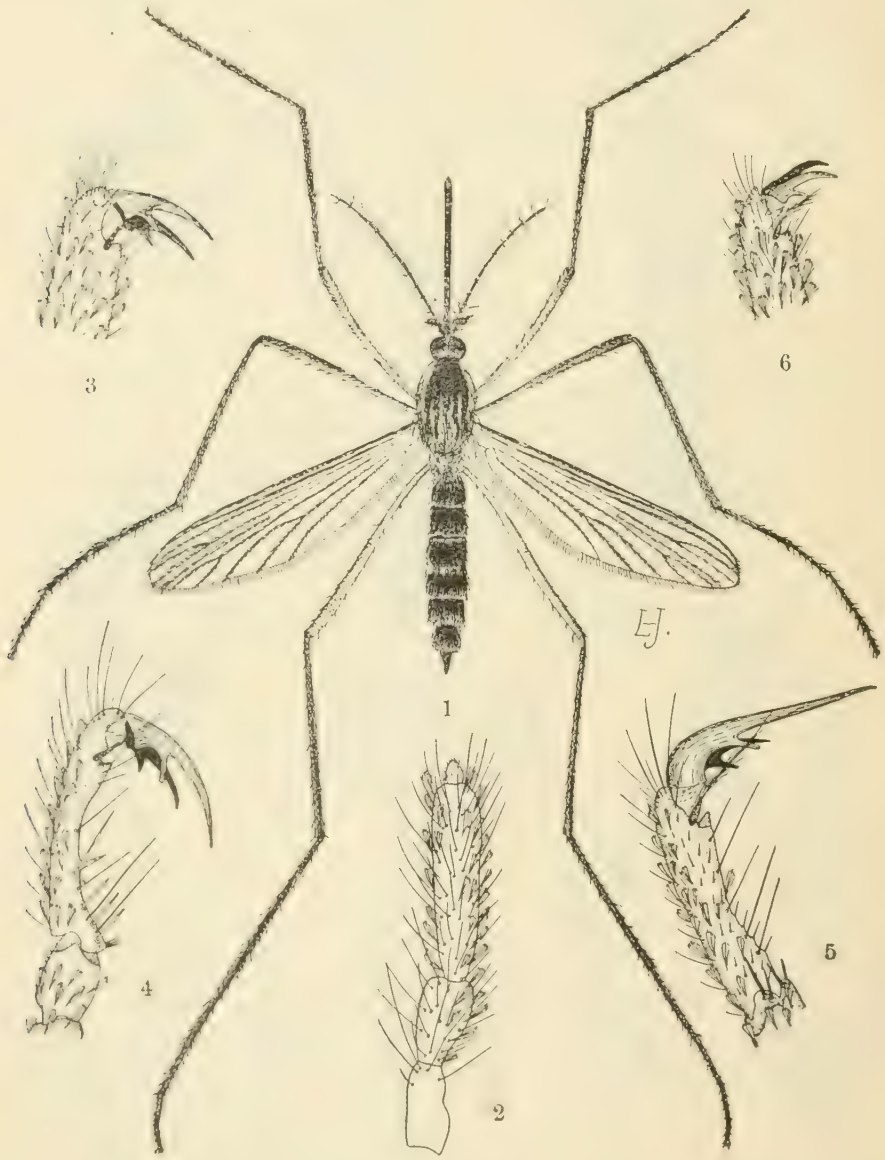

Fig. 105. Adult of *Aedes aurifer* Coq. (After John B. Smith).

1, female adult; 2, palpus of same; 3, anterior claw of same; 4, anterior; 5, middle and 6, posterior claws of male (all enlarged).

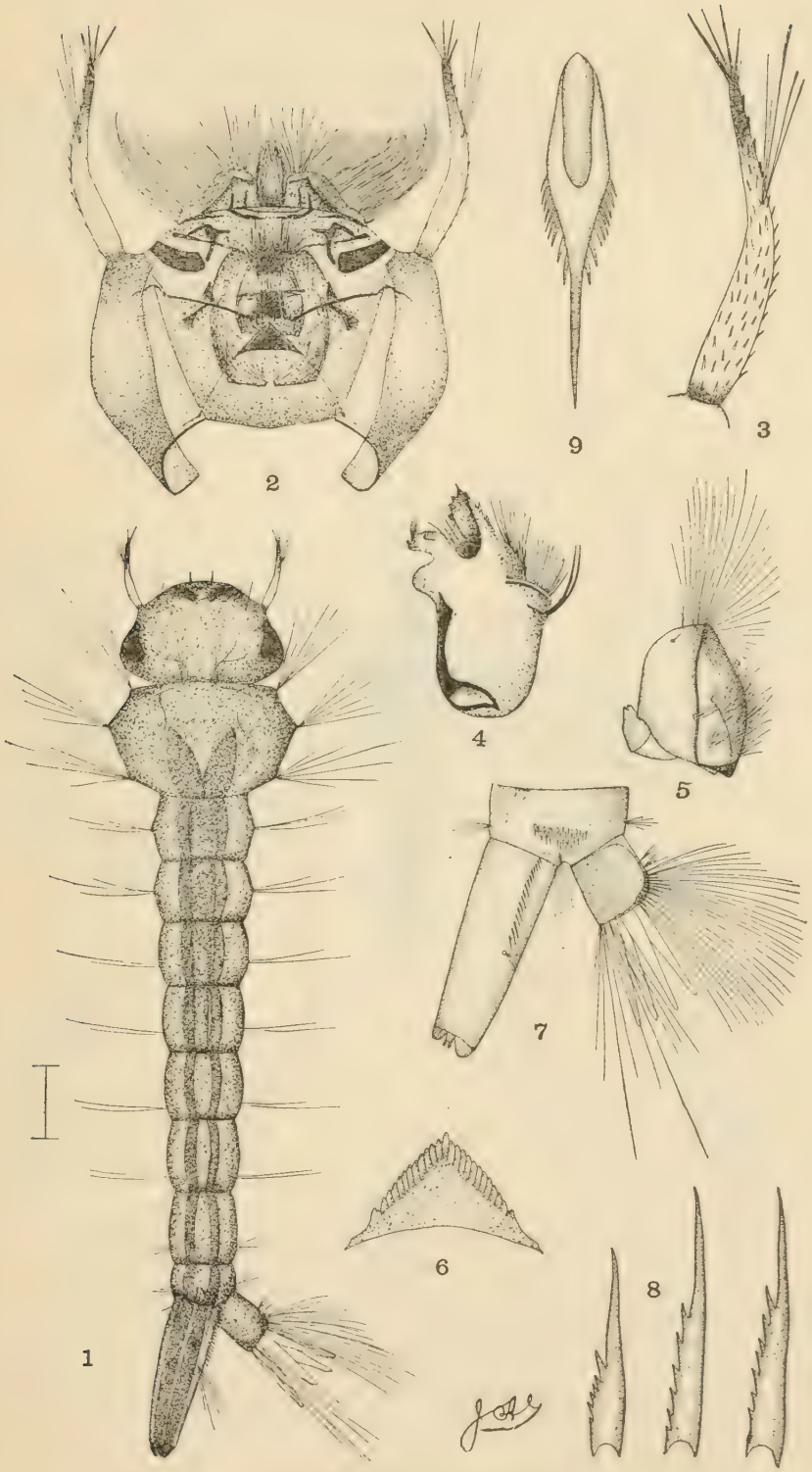

Fig. 106. Larva of *Aedes aurifer* Coq. (After John B. Smith).

1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal segments with siphon; 8, siphonal spines, showing variations; 9, a single scale of the 8th segment (all enlarged).

A. pallidohirta Gross. (*A. fuscus* O. S.), an abberation of *A. fuscus*. Larvae taken from a woodland pool on the Orange mountains; adults emerged May 19, 22. Not found since or elsewhere.

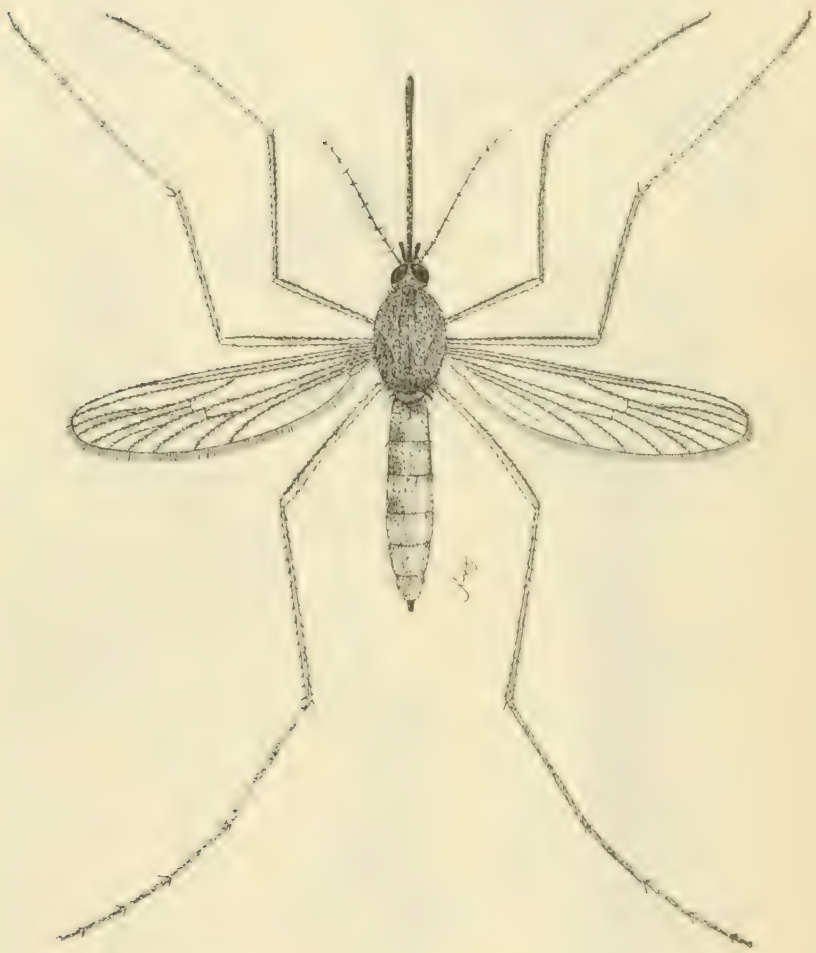

Fig. 107. Adult of *Aedes pallidohirta* Gross. (*A. fuscus* O. S.). After John B. Smith).

A. fuscus Wlk. (The Little Smoky Mosquito). Occurs throughout the state, breeding continuously from April to October, sparingly at first, more abundantly later in the season. The larvae are essentially clean-water forms, and seem to prefer the more permanent bodies of water, but they are occassionally found in puddles and rarely in rain-barrels.

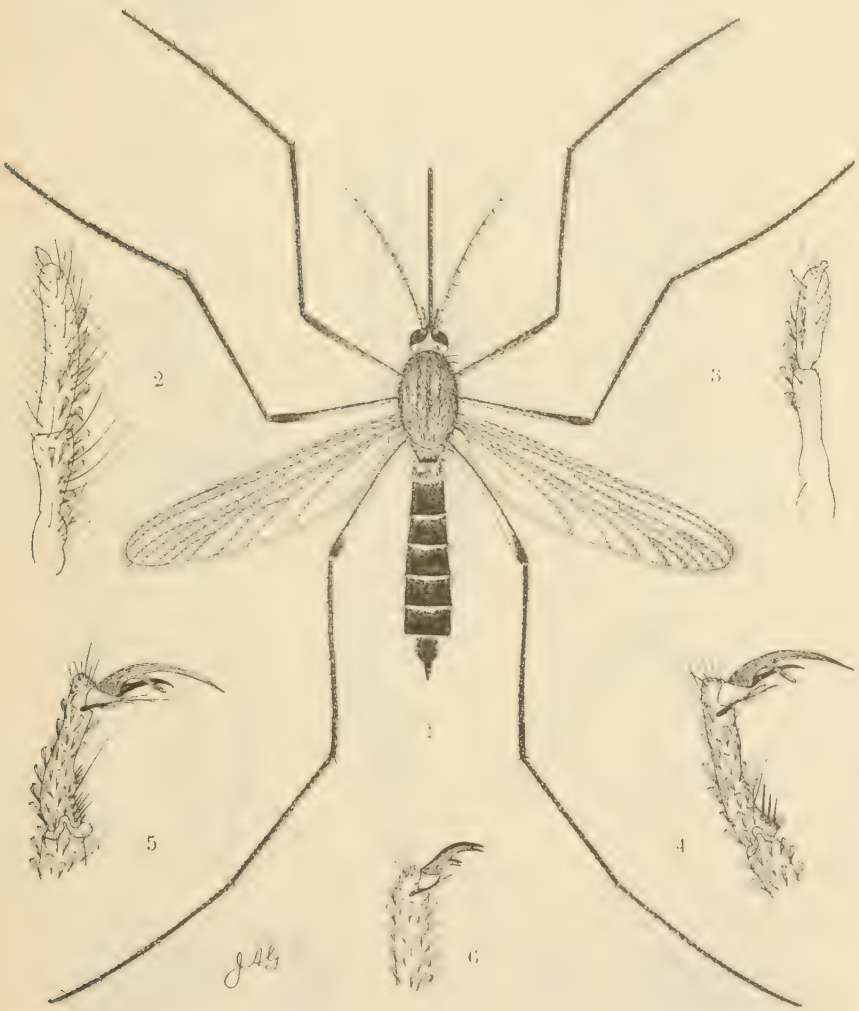

Fig. 108. Adult of *Aedes fuscus* O. S. (After John B. Smith).

1, female adult; 2, palpus of same; 3, palpus of male; 4, anterior; 5, middle and 6, posterior claws of male (all enlarged).

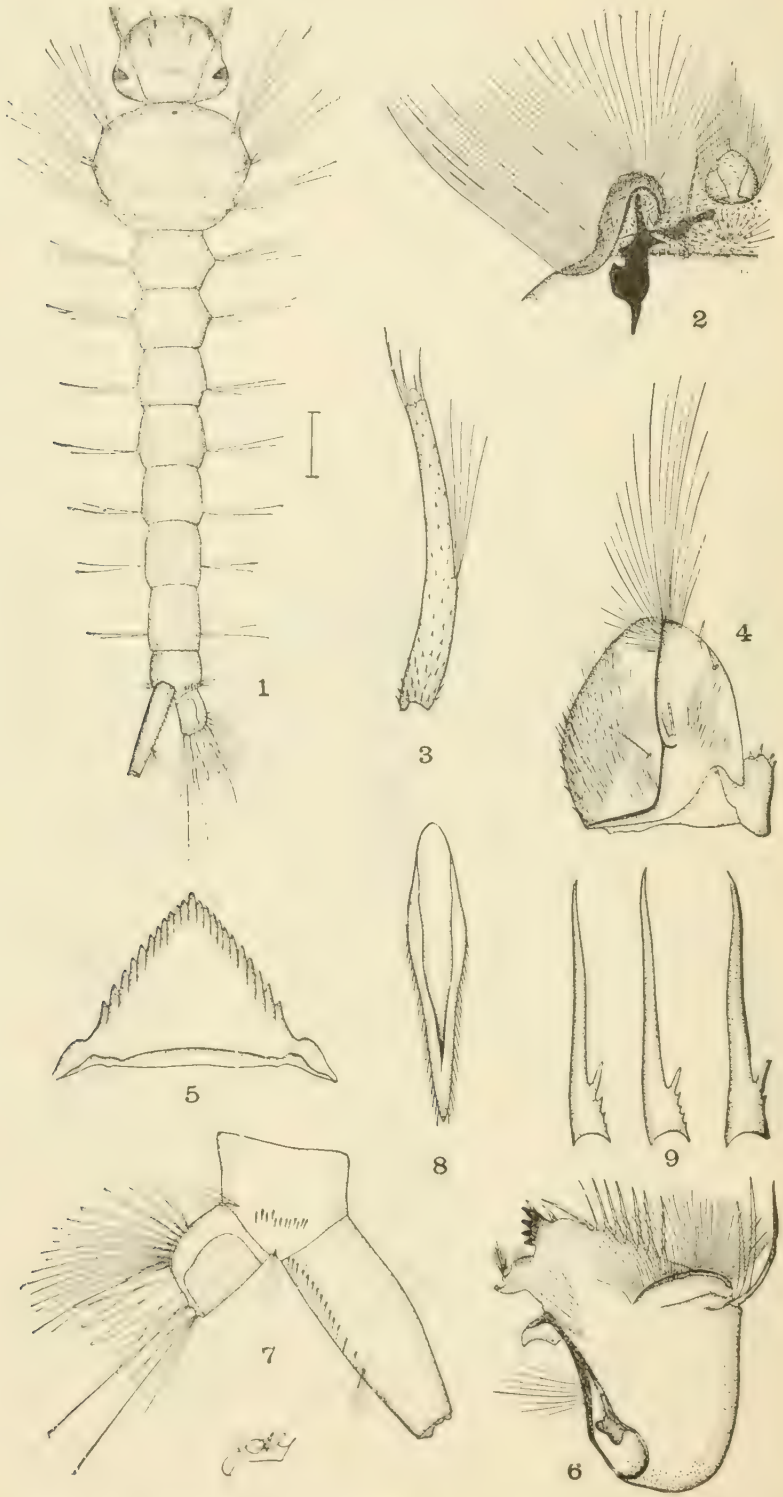

Fig. 109. Larva of *Aedes fuscus* O. S. (After John B. Smith).

1, larva; 2, the mouth brushes; 3, antenna; 4, palpus; 5, mentum; 6, mandible; 7, terminal segments with siphon; 8, a single scale of the 8th segment; 9, siphonal spines (all enlarged).

C. territans Wlk. (*saxatilis* Gross.) (The Little Black Mosquito). Larvae occurred in a rock-bottomed pool on the Garrett mountain, Paterson, August 31, and adults emerged the same day and the one following; it has not been met with since.

Fig. 110. Adult of *Culex territans* Wlk. (After John B. Smith).

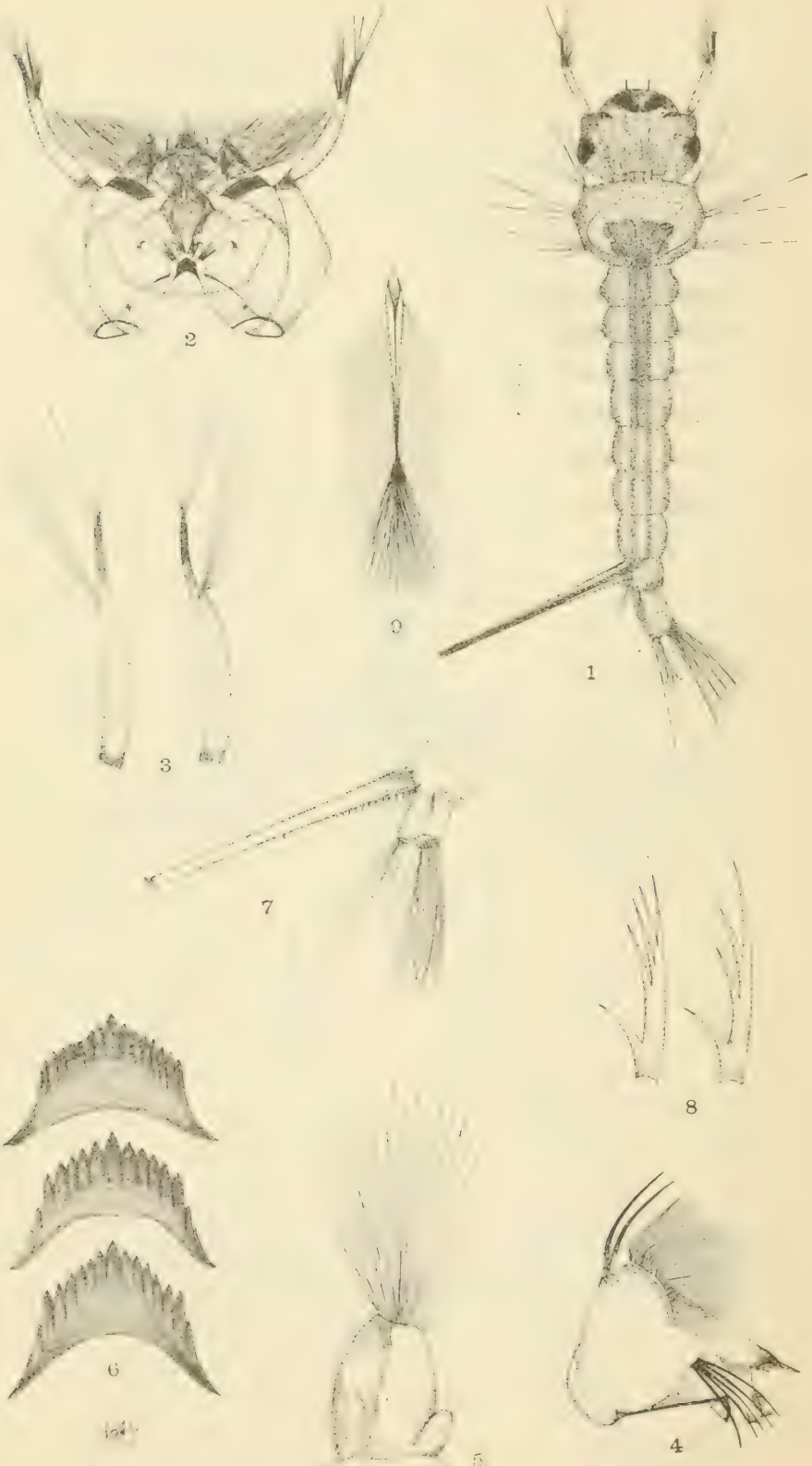

Fig. 111. Larva of *Culex territans* Wlk. (After John B. Smith).

1, larva; 2, head from beneath; 3, antennae; 4, mandible; 5, palpus; 6, variations in the mentum; 7, terminal segments with siphon; 8, siphonal spines; 9, a single scale from the 8th segment (all enlarged).

C. melanurus Coq. (The Black-Tailed Mosquito). The larvae breed and winter in cold spring pools in sphagnum swamps, among the bottom material. They have also been found in early August with the egg boat and many breed all summer. Thus far found only at Lahaway.

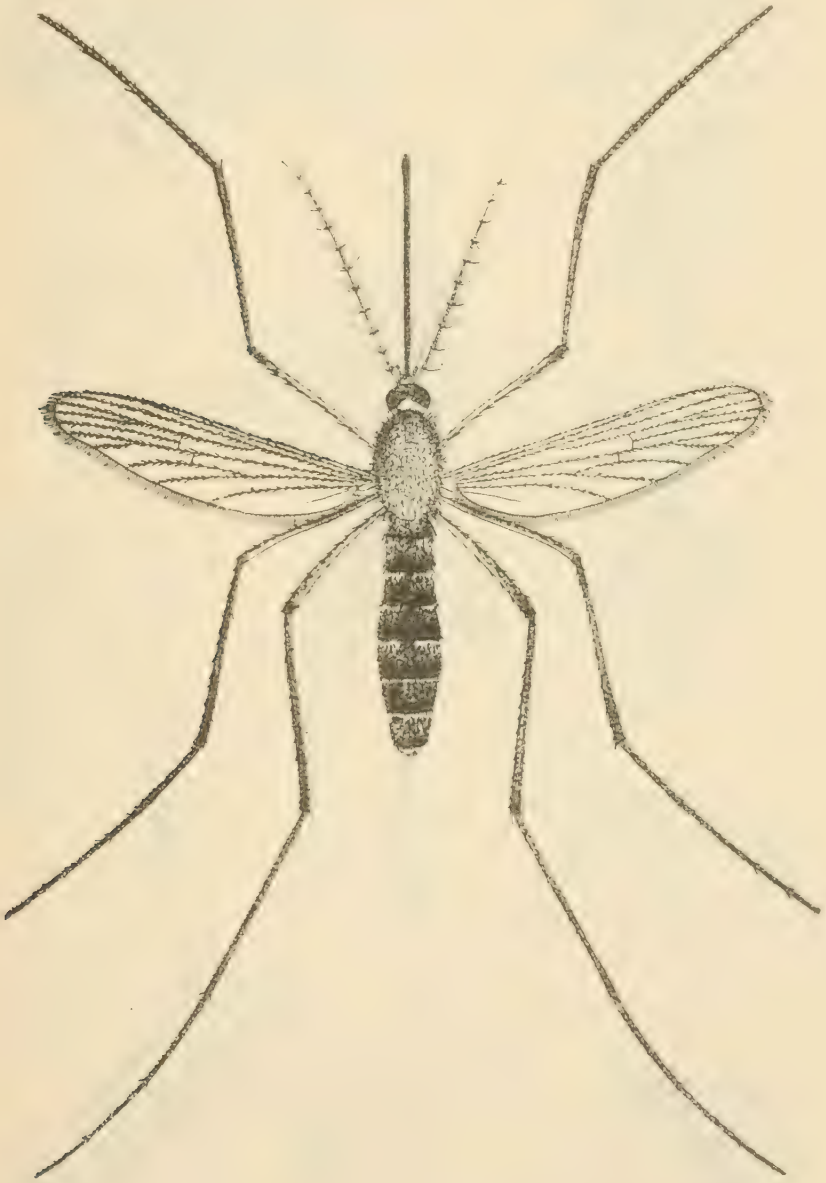

Fig. 112. *Culex melanurus* Coq. (After John B. Smith).

Uranotaenia sapphirina O. S. (The Sapphire-Lined Mosquito). Local, but probably found throughout the state. Larvae have been found in the Great Piece meadows, August 10; Irvington, September 5; Trenton, August 5; Matedeconk Neck, September 23; Lahaway, June; Cape May. Breeds in open swamp area well overgrown with floating vegetation, the eggs laid in boat-shaped masses. The adult is a small insect marked with metallic blue scales and does not bite.

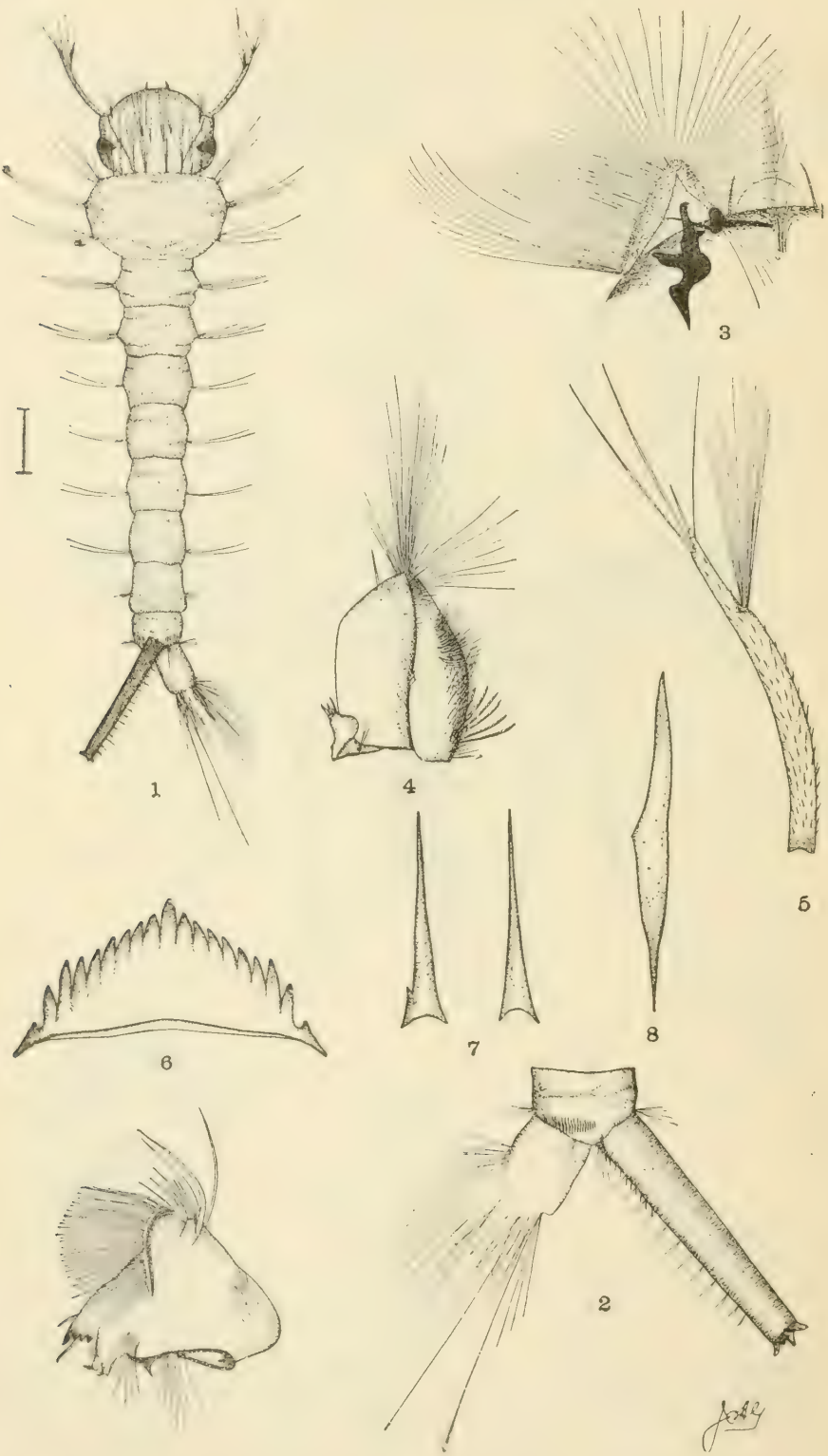

Fig. 113. Larva of *Culex melanurus* Coq. (After John B. Smith).

1, larva; 2, terminal segments with siphon; 3, mouth brushes; 4, maxillary palpus; 5, antenna; 6, mentum; 7, siphonal spines; 8, scale from 8th segment; 9, mandible (all enlarged).

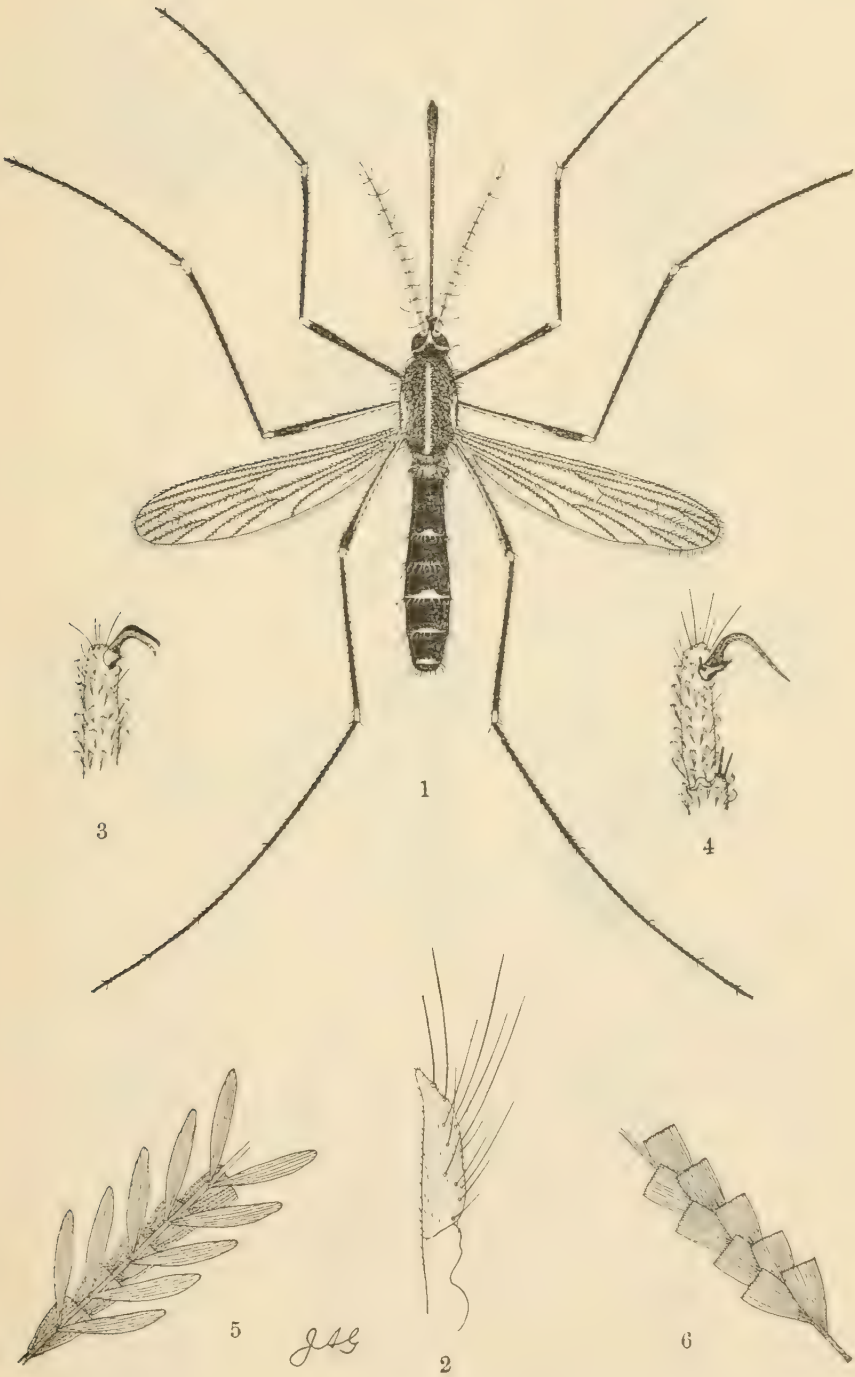

Fig. 114. Adult of *Uranotaenia sapphirina* O. S. (After John B. Smith).
1, female adult; 2, palpus of same; 3, anterior and 4, middle claws of male; 5, part of wing vein near outer margin; 6, part of wing near costa showing scales (all enlarged).

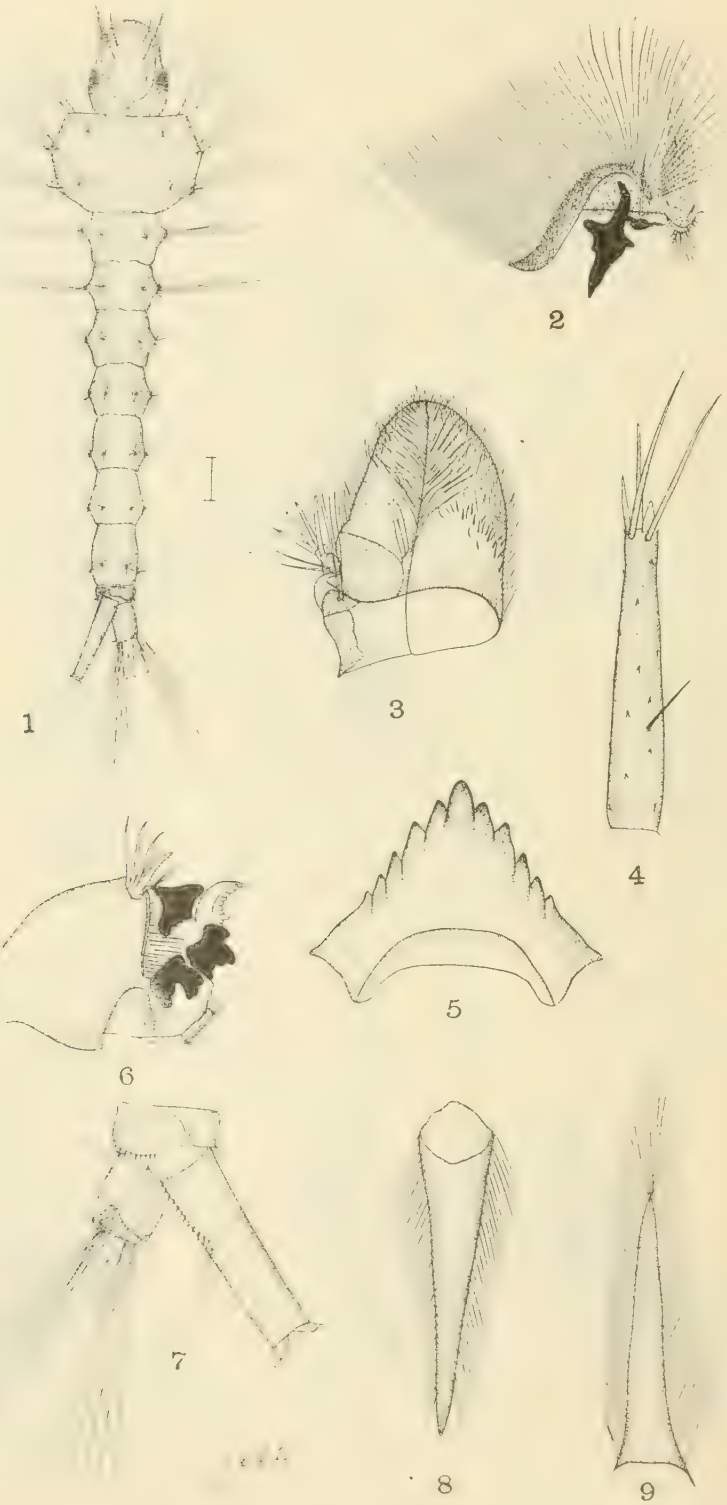

Fig. 115. Larva of *Uranotaenia sapphirina* O. S. (After John B. Smith).
1, larva; 2, mouth brush; 3, palpus; 4, antenna; 5, mentum; 6, mandible; 7, terminal segments and siphon; 8, one of the scales from 8th segment; 9, a siphonal spine (all enlarged).

Wyeomyia smithii Coq. (The Pitcher-Plant Mosquito). Breeds in the leaves of pitcher plants, "Sarracenia," wherever these occur in the state. The adult is a small insect that does not bite and lays its eggs in the leaves, fastened to the sides when they have no water, or on the surface when they are full. Larvae may be found at all times of the year, the winter being passed in that stage, sometimes active in mild weather, sometimes frozen solid. The first adults mature late in May.

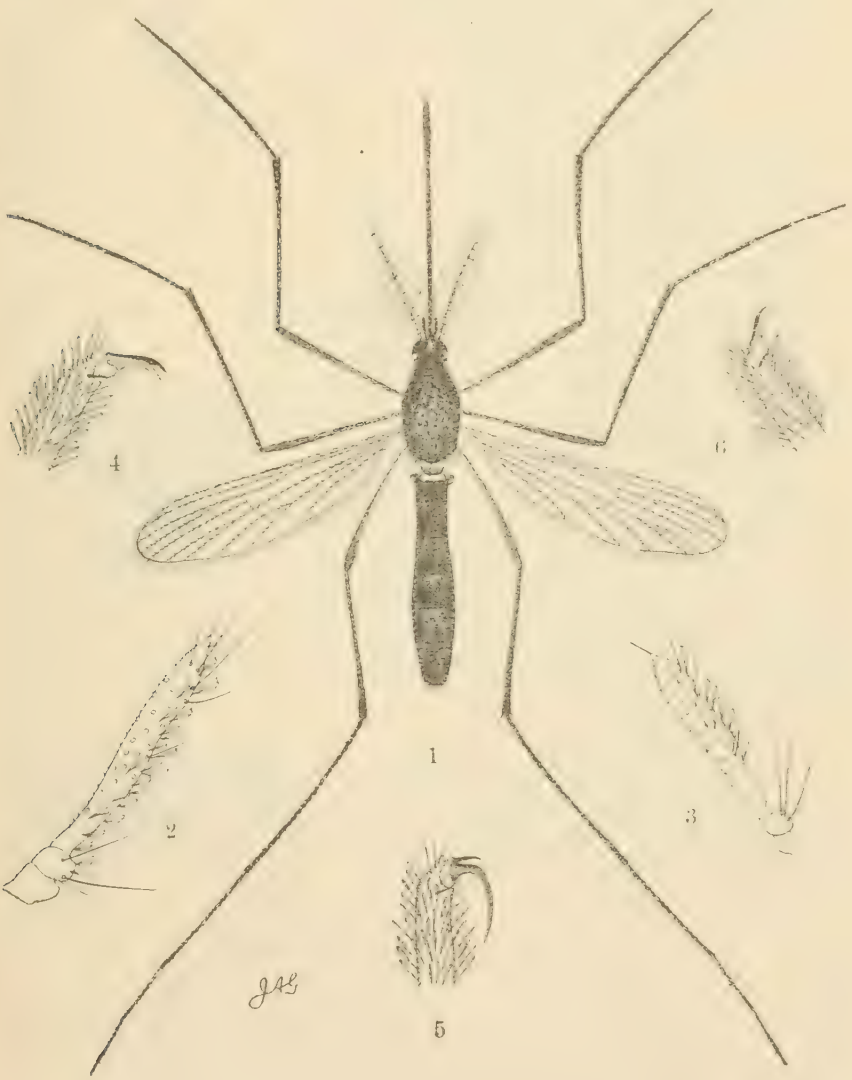

Fig. 116. Adult of *Wyeomyia smithii* Coq. (After John B. Smith).
1, female adult; 2, palpus of same; 3, palpus of male; 4, anterior; 5, middle and 6, posterior claws of male (all enlarged).

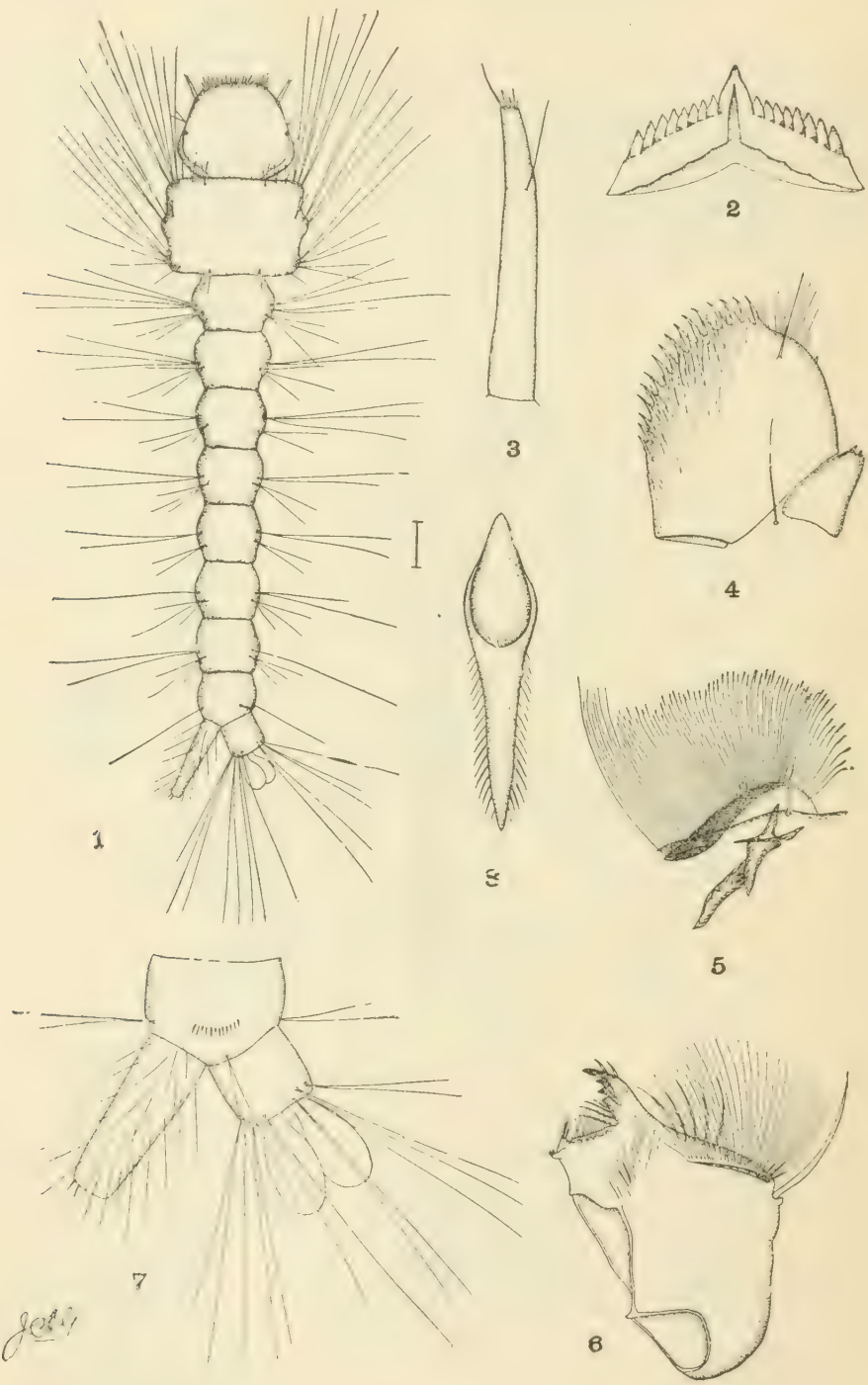

Fig. 117. Larva of *Wyeomyia smithii* Coq. (After John B. Smith).

1, larva; 2, mentum; 3, antenna; 4, palpus; 5, mouth brush; 6, mandible; 7, terminal segments with siphon; 8, a single scale from 8th segment (all enlarged).

The Problem of Mosquito Control

General Considerations

Experience has shown that, until we know more about mosquitoes than is now on record, the most vulnerable point in mosquito life is the larval, or wriggler stage during most of which the creature must live in a water medium. When attack is directed toward this quarter we have merely to eliminate water in which mosquitoes breed and there will be no mosquitoes. This is a beautifully simple statement of an exceedingly difficult operation.

The first problem is the nature of the water in which the economically important species will breed. Are there any aggregations of water in which the economic species will not breed? So far as is known they can not breed in dew because the aggregations are never large nor persistent enough. So far as we know, within the limits of New Jersey, the economic species can not breed in cedar-swamp water. So far as we know, the important fresh-water species can not breed in sea water of over 5 or 6 per cent salinity, nor can any of the salt-marsh species breed in fresh water except as it has been polluted. So far as we known, the salt-marsh species can not breed in water of 25 or more per cent salinity. So far as we know, they can not breed in water when both top and bottom working fishes are present (except as the fish are screened away) because larvae, or wrigglers, are eaten before they can reach maturity.

What kind of water can mosquitoes use? All pools conforming to the following specifications are capable of breeding the economic species of mosquitoes.

1. Size sufficient to immerse the wrigglers.
2. Remain at least practically throughout the immature stages (salt-marsh 7 days in midsummer to 1 month in spring and fall; fresh-water species about two weeks in midsummer to double that or more in spring or fall).
3. Temperature 55° F. or higher.
4. Salinity for salt marsh from 4 to 20 per cent and for fresh water 2 per cent or less.
5. Stagnant or very slow moving water.
6. Absence of wriggler-eating fish or protected by plant screen through which the fish can not penetrate.
7. Not impregnated heavily with mineral acid or the soaking of cedar swamps.

The second problem is the location of the water in which the mosquito will breed. This is found nearly everywhere—sheets of paper,

bottles, bark, tin cans, jars, tubs, buckets, cesspools, cisterns, roofs, roof gutters and valleys, ground pools, edges and eddies of streams, and, in fact, in any place capable of holding water. Breeding places, on the basis of their persistence, may invariably be divided into temporary and permanent.

The third problem is the extent to which one part of the area may be influenced by mosquito flights from other parts, and the extent to which the area may be influenced by mosquito flights originating from breeding which occurs entirely outside its limits. The principal salt-marsh species with favoring weather conditions can cover from 30 to 60 miles. The fresh-water swamp mosquito under extremely heavy breeding conditions have been known to migrate 10 miles and the house mosquito 2.5 miles. The blood hunger and the instinct to lay eggs appear to be the actuating courses of movement, but the conditions and geography appear to exert modifying influences.

The fourth problem is one of making a survey of the mosquito conditions in and adjacent to the territory selected for protection. This involves the location of all permanent breeding places, as nearly all temporary breeding places as possible, the determining of the danger and the source of possible invasions of mosquitoes from breeding grounds outside the area, and the preparation of plans and estimates for efficient control work. These plans and estimates should include adequate temporary work to afford immediate relief and such an amount of permanent work as will in a period of a few years leave nothing but a minimum of maintenance to continue the protection. Unless the territory is very large, such a survey usually costs only a few hundred dollars and can ordinarily be financed by state or local organizations.

The fifth problem is one of financing the work. The charge should very properly be borne by the people receiving the benefit. In order that they may be willing to do so, a campaign of education must be undertaken. Lectures must be given; newspaper and magazine articles must be prepared. Local committees to push this work in every community should be formed, and will be found exceedingly helpful. The cost of such a campaign is usually small and can ordinarily be financed with local funds.

The sixth problem is the creation of an effective organization to carry out the work of mosquito control. This involves the establishment of an agency which is fitted to command public confidence, has an expert knowledge of mosquito problems and is furnished with a

high degree of executive ability. In New Jersey, at least, and it is suspected elsewhere, the form of organization most likely to command public confidence is an unpaid board of the strongest citizens of the area concerned. These men, by reason of their community standing, instantly inspire confidence. They can not be secured on a salary basis because they are already earning many times the sum that an effort of this type could pay them. If they are not, they are not sufficiently alive to head a public effort of this kind.

The expert knowledge of mosquito problems will normally be furnished by an employee operating under the direction of this unpaid controlling board. In many cases the mosquito expert can carry the executive side of the work as well. When such a combination cannot be secured, one man must be selected for his executive ability and another for his knowledge of mosquito problems. Responsibility for results should be fixed upon the executive and he should be allowed the fullest possible freedom in the selection and dismissal of his assistants.

The seventh and last general problem is the meeting of invasions of mosquitoes bred outside the area. Ordinarily there will be a strong aversion, on the part of the people living within the area, to the expenditure of local funds outside the area, even if they may expect to profit largely thereby. This will be especially true if the outside areas in question are inhabited by people, whom it seems should be able to take care of such breeding places for their own benefit. It is at this point that an authority coming from outside the protected area and areas adjacent thereto should be of service, and such a general organization becomes still more imperative as adjacent local areas take up the work of mosquito control. This general organization can correlate and supplement efforts, especially if it has funds, in such a way as to eliminate the sources from which mosquito invasions come, in the shortest possible space of time. In order that the general or correlating organization may be really effective it must have some real power in the conduct of local affairs.

Mosquito Flight

The practical work of mosquito control has gone far enough to demonstrate that migrating adults of various species of mosquitoes frequently so complicate the problem of freeing a limited area as to render successful work impossible. This fact, when taken with the further fact that interest in the practical problem of control is

growing, would seem to justify an examination of the data bearing upon mosquito migration in the hope of finding out how to minimize its effects.

Extent

Howard,Dyar and Knab[8] have brought together a mass of data bearing on the question of mosquito migration. As might be expected, there is much evidence of flight without any indication of the species concerned, but there is also much where the species has been determined. Table 1 will serve to give the facts.

Table 1

Data on Mosquito Migration

Date	Investigator	Place	Species	No. of Miles
1879	Mitchell	Matagorda Bay	Unknown, probably salt-marsh	50-60
1884	Hetherington	Ship "Gedney"	Unknown	27
1886	Mitchell	Matagorda Bay	Unknown, probably salt-marsh	50-60
1903	Russell	Ship "Newark"	*An. annulipalpis*	2
1904	Smith	New Jersey seacoast and bay coast	*A. sollicitans, A. cantator*	30-40
1904-1908	Carter	Gulf of Mexico off Louisiana coast	Salt-marsh	15-18
1910	Mayer	Dry Tortugas	*A. niger,* Salt-marsh	60
1909	Young	Ship "Concho"	Unknown	60

It thus appears that the far-flying species are those which breed on the salt marshes, that 25 or 30-mile movements are common, and that extremes of 60 miles may be reached.

The writer has traced the salt-marsh species *A. cantator* and *A. sollicitans* during each of the last seven summer seasons and has found them penetrating the back country for long distances. Twenty-five-mile migrations are common, and 35 to 40-mile migrations take place when the brood emerging is very large. *A. cantator* has not been observed to cover the distances reached by *A. sollicitans,* but the difference may be due to the cooler weather and the smaller broods of the former.

[8]Howard, L. O., Dyar, H. G., and Knab, Frederick, 1912. The Mosquitoes of North and Central America and the West Indies, v. 1, p. 339-245.

Russell (table 1) as shown a flight of 2 miles for *Anopheles annulipalpis*. LePrince and Orenstein[9] have cited incontrovertible evidence to show a flight of 6,250 feet by *Anopheles tarsimaculata* and *Anopheles albimanus*. (The latter is a very important carrier of malaria).

Headlee[10] has collected evidence to show the movement of the house mosquito *(Culex pipiens)* from an area of very intense breeding to a point fully 2.5 miles away.

Smith[11] records that the fresh-water swamp mosquito (*Aedes sylvestris)* may migrate as far as 5 miles. In the month of May, 1917, heavy rainfall flooded a large part of the upper Passaic Valley, which contains many thousands of acres of fresh-water swamp land. While the waters were still spread over a large portion of this swamp-land, R. W. Gies and W. V. Becker traversed a large portion of it in a canoe and found very small larvae of the fresh-water swamp mosquito *(Aedes sylvestris)* everywhere in the quiet water. The water fell with sufficient rapidity to destroy the breeding on the better-drained portions of the valley, but enough escaped from the undrained sections to make trouble in June.

To the north and west of this valley lay successive ranges of low mountains beginning at an elevation of about 400 feet and increasing rapidly in height, with gaps leading only to higher elevations and sparse population. To the south and east lay two ridges of low mountains with an extreme height of a little over 400 feet, and with deep gaps leading out upon level or rolling plains of low elevation and dense population.

On June 15 a series of daylight collections made from Newark to and across the upper Passaic valley showed the fresh-water swamp mosquito in constantly increasing numbers from East Orange to Hatfield swamp, the nearest piece of swampland in this valley, and in rapidly decreasing numbers until the collecting ceased on the north shore of the valley. From East Orange to Hatfield swamp, as the crow flies, is about 7 miles, in the course of which the two beforementioned ridges rear their crests. By the roadway followed in making the collections the distance was about 10 miles.

Beginning on June 20, series of collections were made on all sides of the upper Passaic River valley. These collections show a rapidly

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[9]LePrince, J. A., and Orenstein, A. J., 1916. Mosquito Control in Panama, p. 94-114.

[10]Headlee, Thomas J., 1917. Some recent advances in the knowledge of the natural history and control of mosquitoes. N. J. Agr. Exp. Sta. Bul. 306

[11]Smith, J. B., 1904. N. J. Agr. Exp. Sta. Report on Mosquitoes, p. 250.

disappearing density to the north and west, a more slowly diminishing density to the south and east, and the greatest density in the areas facing the gaps which lead from this valley to the south and east.

Inasmuch as the fresh-water swamp mosquito by this date had had time to effect its distribution: (a) the low and rapidly decreasing density to the north and west may be taken to indicate that movement in that direction was slight; (b) the more slowly decreasing density to the south and east may be taken to indicate that the movement in this direction was more pronounced; (c) the greater and more slowly decreasing density in the areas which face the gaps leading from this valley to the south and east may be taken to indicate that the principal movement occurred through these gaps.

Cause of Mosquito Flight

The cause of mosquito migrations is obscure, but it is safe to assume they are in some way related to one or both of the great necessities of living matter—persistence of the individual and the reproduction of its kind.

The mosquito emerges, its body wall hardens, its parts become adjusted, and it flies away in search of food and opportunities for reproduction. Usually these desired conditions are found nearby. The female alternates between places where food may be had and places where eggs may be laid.

This is the type of movement exhibited by the mosquitoes that breed about human habitations (the house mosquito), and the underlying causes are very evident.

When the same species breeds intensely on a very large area, it tends to move from the place of breeding and may cover in some cases a distance of 2.5 miles. The movement must be made in response to a desire for food, because opportunities for reproduction are unlimited. No doubt the specimens that find food near the place of birth return to the source for reproduction, but those which migrate farther for food find breeding spots nearer the source of food supply. There is no evidence to indicate that this movement of the house mosquito takes place rapidly, but the facts in hand point rather to a slow dissemination.

When dealing with a species that lives in the wilds, such as the more important *Anopheles* (malaria-carrying kinds), the movement to secure food may take on a very different character. LePrince and Orenstein have shown that *Anopheles albimanus* and others

made their way for a distance of ½ mile to a village, apparently in search of food, and that they or others of the same species made a return flight before morning.

The fresh-water swamp mosquito when bred in small numbers seems to have the same movement as the house mosquito, but when produced in enormous numbers, over a large area, may cover long distances in its search for food. Under such circumstances it is likely to find breeding places near its food supply and probably returns rarely to the place where it was bred.

A small brood of salt-marsh mosquitoes *(A. cantator* and *A. sollicitans)* will travel only a short distance for food and return to the marsh for laying eggs, but a very large one will throw off an immense number of migrants which will fly for long distances over territory in which no suitable breeding ground exists. Of course, such flights multiply the insects' chance for obtaining food and also in some cases lead to new breeding grounds. The fact that most of the migrants exhibit undeveloped ovaries does not necessarily mean that breeding cannot take place when the new breeding grounds are reached.

It seems as if intense breeding over large areas is followed by wide distribution of the adults of the house mosquito *(Culex pipiens)*, the fresh-water swamp mosquito (*Aedes sylvestris*) and the salt-marsh mosquitoes (*Aedes cantator* and *Aedes sollicitans*). It is possible that under similar conditions *Anopheles* (some of which carry malaria) would be found to act similarly.

External Factors Which Influence Flight

Without doubt, low temperature reduces, may suspend, or even destroy, the activity of the adult mosquito. Excessively high temperature always retards mosquito activity. A warm temperature, 80° F., is extremely favorable.

Light is avoided by most species and some have such an abhorence of it that they will not become active while it is strong.

Atmospheric moisture has a very powerful effect upon the adult. High percentages are favorable and low percentages deadly. Rain itself is decidedly injurious and prevents adult mosquito activity.

Air movements greatly influence mosquito activity. A stiff breeze is usually quite sufficient to stop their movements and to compel them to cling to shelter. Winds of low velocity (10 miles an hour or less), of high temperature (about 80° F.) and high humidity appear to be the ones that favor long flights.

The observations of practically all investigators indicate that the salt-marsh species in long migrations travel with the wind.

On the other hand, LePrince and Orenstein found the *Anopheles* flying either against the wind or at right angles to it. Russell, however, records *Anopheles annulipalpis* as coming aboard ship on a breeze from land.

The zone of the house mosquitoes described by Headlee did not extend in the direction of the favorable winds. The mosquitoes seem to have moved in the direction of dense population.

The migrations of the fresh-water swamp mosquito extended southward and eastward much farther than northward or westward, while the more favorable winds would seem to urge it in opposite directions. It is quite possible that the ranges of low mountains with which the home of this brood of the swamp mosquito was surrounded may have had something to do with the direction of migrations, for the openings lay to the south and east. To go to the north and west was to encounter a succession of ridges, while to migrate southward meant much easier going.

Conclusions

The ordinary short flights of all species between food and breeding places that serve to keep the species going in localities where they are already established, in all probability are initiated by food and breeding-place odors. That these stimuli may excite movements of considerable distances is indicated by the studies of LePrince and Orenstein in Panama.

However, when, we consider the long-distance flights of any species, the breeding conditions of which have been carefully studied, we find that they arise only where the species concerned has bred very intensely over a large area.

Naturally, under these conditions the food supply would be less than normal and the flight might be due to that fact.

Air currents, so long as they are not too high to prohibit movement, would seem not to affect in any important way the short ordinary flights, but seem to be a determining factor in long-distance movements. Ordinarily the flight in such cases goes with the slow-moving, warm, damp wind, but modifications in direction of flight may be due to mountain ridges and possibly other factors not at present recognized.

Bearing of These Facts on the Problem of Control

The facts just set forth show clearly that flights of salt-marsh, fresh-water swamp, malarial and house mosquitoes may seriously interfere with the project of keeping a specified locality free from mosquitoes, and indicate that plans and estimates for practical control work must be based on something more than a study of the mosquito-breeding places within a specified area—must include an analysis of the mosquitoes on the wing throughout the said locality for at least one summer season. They show further that the practical work of control must be accompanied by a thorough knowledge of the adult mosquitoes that are abroad in order that the trouble due to local breeding may be distinguished from that arising from invasions, and in order further that the sources of the invading pests may be found and eliminated.

Mosquito Surveys

A good contour map should be secured on a scale of at least 12 inches to the mile. A careful search for mosquito-breeding places should be made and all permanent ones should be shown on the map and each given a number. The detailed report, which should be prepared, should discuss each place in detail and show not only the type of elimination deemed best but should indicate the cost of the operation. Careful record of the temporary breeding places found should be kept and the report should indicate the amount of labor their suppression will probably entail.

A series of maps, preferably of a contour type, showing the mosquitoes on the wing for at least one summer season, should be prepared. There will be one map for each month of the season. The report should analyze their breeding and indicate the sources from which the mosquitoes come.

The environs of the area should be studied for possible sources of mosquitoes occurring within the area, and the report should indicate the importance and the means of getting rid of these outside breeding places.

A careful study of the nature of the organization necessary to carry out the mosquito-suppression work in the district must be made and the report should make definite recommendations and present definite estimates.

The survey should result in fully developed plans and estimates for effective work.

Practical Procedure in Mosquito Control

Let it be assumed that the preliminary survey work has been completed, a detailed report prepared, preliminary educational work done, a fairly sufficient sum of money secured, and an organization created to carry on the work. What is the nature and course of the practical operations?

Financial Arrangements

With the exception of about 10 per cent, which should be reserved for emergencies, the whole available sum should be divided into two parts, one of which is to support the temporary work and the other the permanent operations. Obviously, the organization must do enough temporary work to afford marked relief or later support will probably be difficult if not impossible to obtain, and equally true is it that a certain amount of permanent work must be done or the demand for more complete protection, which is certain year by year to become more insistent, can not be met.

Under the head of temporary work certain amounts should be allotted to supervision, certain amounts to inspection, certain amounts to equipment, supplies and labor. Under the head of permanent work a certain amount should be allotted to supervision, a certain amount to engineering and a certain amount to contractual obligations. If it should be found that the permanent work can in any or all cases be most satisfactorily done with the organization's own laborers, the moneys set aside for the payment of contractural obligations may be divided in equipment, supplies, and labor.

Not only should the budget be made for the year but, in order that the directing agency may exercise a real check upon the rate of expenditures, the yearly budget should be built upon a monthly or even a shorter unit-period basis. Without some such scheme, apparent emergencies may arise and consume the appropriation, leaving nothing for the still greater emergency or at least leaving the organization, at the end of the season, with little to show for its labors.

At each regular meeting of the controlling agency the financial statement should show:

1. Total expenditure for the entire preceding period.
2. Total expenditure for preceding unit-period.
3. Balance on hand.
4. Bills payable and bills receivable.

5. Balance when all bills are paid.
6. Balance of appropriation not yet in hand.

The controlling agency should scrutinize carefully the expenditures of the preceding unit-period in comparison with the budget estimates for that period.

Temporary Work

The purpose of temporary work is to afford immediate protection to the population of the protected area. This involves a knowledge of the breeding in all temporary breeding places as well as in the permanent ones before the larvae have a chance to transform to adult mosquitoes and, indeed, in time to permit the completion of temporary treatment before emergence can take place.

When salt marsh, woodland-pool or fresh-water swamp species are to be met, this knowledge should be in hand not later than the middle of April in New Jersey, for between that time and emergence there is usually a period of a little over two weeks and rainy weather may interfere with the application of control measures.

Up to May first the number of men engaged in the finding of breeding may be small because the period during which they have to cover the area is long. But after that date the force should be sufficient to cover the entire upland area thoroughly once every two weeks and the salt-marsh once every week. Salt-marsh inspection needs will vary tremendously with the weather and it is practicable to reduce the amount of inspection given to it under dry weather conditions far below the point to which upland inspection can be reduced under similar weather conditions. This is true because the salt marsh is open and easily seen while the upland is more or less wooded and covered with homes and other buildings. As a rule, the New Jersey inspection practice now operating falls considerably below this requirement and the mosquito trouble to which some of the protected areas are subject is largely traceable to this fault in operation.

In areas where neither salt marsh, fresh-water swamp, nor woodland-pool species are found inspection may be delayed until May 1 or possibly even until May 15.

When breeding is found it should be destroyed by filling to grade, draining, stocking with fish (which must almost invariably be accompanied by cleaning and sharp edging), or treating with larvicide or covering with oil.

The difference between the temporary work necessary during a dry season and that which is necessary during a wet season is enormous. It is the water surface which measures mosquito-breeding possibilities and wet weather may increase it a hundredfold or more. It is therefore possible that any force working upon temporary work under wet weather conditions may be helpless. In such cases the public should be informed of the fact and warned to expect mosquito trouble. Good judgment on the part of the supervisor, and faithful performance on the part of his subordinates will go far toward securing control when the conditions are most unpromising.

Temporary control work should not be limited to the area itself but should include all territory contributing to the supply of the pest which troubles the population of the protected area. In many cases this will involve the use of influence and the promotion of education. In others it will involve the actual expenditure of funds.

Some measure of the reduction in mosquito numbers must be devised. Reports of householders can be depended on only when the reduction is very complete. The writer believes that this measure can best be found in the practice of regular twice-a-week evening collections of mosquitoes on the wing and the prompt charting of the results. Unless this work is properly done it will prove a waste of time and money. The methods involved in the proper practice of the periodic collection are set forth on pages 91-95.

Cleaning and Stocking With Fish

This method is to be employed only when the pools are highly valued for some reason or another. Some pools will have a screening growth only around the edges. In many cases the dropping of the water level 12 inches about June first will expose a clean rim of beach all around the body of water and thereby permit the fish to swim in and consume all the wrigglers. No serious amount of growth will usually take place during the balance of the mosquito season. At the close of the season the water should be returned to the original level and kept there until the following June in order that all plant growth upon the previously exposed area may be killed. In other cases plant growth will occur more or less throughout. Ordinarily nothing short of deepening will improve this situation. Most large pools, ponds and lakes are already stocked with fish. Both top- and bottom-feeding fish are desirable but the former

Fig. 118. A well cleaned brook.

is especially important, because most of the important species come to the surface for air. Normally small fish are better mosquito exterminators than large ones. Gold-fish may be used where they are preferred to other species.

Larvicides

This term is usually applied to some substances destructive to mosquito wrigglers, which will mix with the water. A large number of these substances have been tried, as set forth in the following summary, but the ideal is yet to be found. Such an ideal larvicide should destroy quickly all mosquito larvae with which it comes in contact, should be non-poisonous to man and the higher animals, should be non-injurious to water plants, should remain effective in the pool throughout the season even when it becomes dry and refills many times, and should be cheap enough to render its use practicable under ordinary mosquito-control conditions.

Sodium Chloride and Calcium Chloride (NaCl and $CaCl_2$). The work on these substances confirmed the results obtained by Chidester[12] and showed that the amount necessary (of NaCl and $CaCl_2$) was such as to render the use of either impracticable from the standpoint of cost.

Sodium Hydroxide (NaOH). The resistance of fully-grown larvae of *A. cantator* and *A. sollicitans* to NaOH was determined by adding it to creek-water (2.9 per cent salinity) in doses ranging from 0.0001 gm. to 0.2 gm. per 1,000 cc. Two-tenths of a gram had killed everything in 3 days. Another test, in the course of which tap-water was substituted for creek-water, was then set up with amounts of NaOH ranging from 0.5 gm. per 1,000 cc. In two days some killing was visible in the 1-gm. solution, more in the 5-gm., and complete killing in the 20-gm. A brown precipitate appeared in all jars from 0.1 gm. up.

Sodium sulfo-carbonate. (A commercial article, not C. P. It was prepared by the Dow Chemical Company.) This compound was used in testing the resistance of fully grown larvae of *A. cantator* and *A. sollicitans* in tap-water to a strength ranging from 1 to 3 cc. of the material to 100 cc. of water. In two days the larvae had transformed to pupae and some adults had emerged.

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[12]Chidester, F. E. 1916. The influence of salinity on the development of certain species of mosquito larvae and its bearing on the problem of the distribution of species. N. J. Agr. Exp. Sta., Bul. 299.

Borax. (Marked "refined," and furnished by Eimer and Amend.) The resistance of 2 to 4-mm. *C. pipiens* larvae to borax in tap-water, in amounts ranging from 3.5 to 20 gm. to 1,000 cc. was tested. In the first six days the larvae seemed to be quite normal. The charge was then increased so that the amounts ranged from 30 to 50 gm. In two days more everything seemed normal. Two days later the charge was in every case increased to 100 gm. In one day more there were no changes.

Copper sulfate. The resistance of 2 to 4-mm. larvae of *C. pipiens* to copper sulfate in tap-water ranging from 1 to 20 gm. to 1,000 cc. was tested. In one day all in 20 gm. were dead, and most of those in 10 gm. had succumbed. In one day more all in 10 gm. and all in 5 gm. were dead. In one day more all in 1 gm. were dead. The dosage for killing in 48 hours seems to be 5 gm. to 1,000 cc.

Iron sulfate. (American Steel and Wire Co. product.) The resistance of 2 to 5-mm. larvae of *A. sollicitans* to iron sulfate in tap-water, with amounts ranging from 2.5 to 50 gm. per 1,000 cc., was tested. Two days later all were dead in the 50-gm. solution, but all in weaker strengths were alive.

Pyrethrum. The resistance of *C. pipiens* larvae ranging from 3 to 6 mm. in length, by placing amounts ranging from 1 to 10 gm. to 100 cc. of tap-water, was tested. The mixture was allowed to stand over-night and 25 specimens placed in each jar the following morning. In one day all were dead in the tested jars. The same process was then repeated by using strengths ranging from 1 gm. to 2,000 cc. down to 1 gm. to 10,000 cc. In two days all larvae were dead. The test was then turned around, and jars in which the larvae had been placed in tap-water were treated with a water extract of pyrethrum at strengths ranging from 7 gm. to 3,000 cc. to 1 gm. to 20,000 cc. In 1 day all were dead in the 1 to 2,000 cc. solution; in 2 days all were dead in the 1 to 3,000; in 3 days all were dead in the 1 to 20,000 solution.

Nicotine. The resistance of 5-mm. larvae of *A. sollicitans* to 40 per cent nicotine in tap-water at strengths ranging from 1 cc. to 1,000 cc. to 1 cc. to 40,000 cc., was tested. In one day all larvæ were killed in the 1 to 10,000 solution or greater. Also, the resistance of 2 to 4-mm. larvae of *C. pipiens* to nicotine, in tap-water, was tested, at strengths varying from 1 cc. to 30,000 cc. to 1 cc. to 60,000 cc. In 2 days all were dead in the 1 to 40,000 solution, and in 4 days all were dead in the 1 to 60,000.

Quassia. A water extract of quassia was prepared by macerating

50 gm. of quassia chips in 50 cc. of distilled water. The resistance of 2 to 4-mm. larvae of *C. pipiens* to quassia, in tap-water varying from 1 cc. to 1,000 cc. to 50 cc. to 1,000 cc. was tested. In 2 days all were dead in the 50 to 1,000 solution. In 3 days no further killing was visible.

Hellebore. The resistance of 2 to 4-mm. larvae of *C. pipiens* to hellebore, in strengths ranging from 6 to 40 gm. to 1,000 cc. of tap-water, was tested. Eight hours before the larvae were introduced the hellebore was placed in the water and thoroughly mixed with it. In 2 days all were dead in the 40 to 1,000 solution. In 3 days a few were dead in the 30 to 1,000 solution. In 8 days all were dead.

Ginger. The resistance of 2 to 4-mm larvæ of *C. pipiens* to ginger, in strengths ranging from 0.5 to 5 gm. per 1,000 cc. of tap-water, was tested. In 1 day all were dead in the 5 to 1,000 solution, and most of the specimens were dead in the 2 to 1,000 solution. In 2 days all were dead.

Pyroligneous acid. (The purified product made by the Mallinkodt Chemical Works.) The resistance of 2 to 4-mm. larvae of *C. pipiens* to pyroligneous acid in tap-water at strengths varying from 1 cc. to 1,000 cc. to 1 cc. to 40,000 cc. was tested. At the end of 6 days all were alive.

Carbo-sul. This is a commercial preparation. It is an emulsified carbon disulfide. The resistance of fully-grown larvae and some pupae of *A. cantator* and *A. sollicitans* to carbo-sul was tested in tap-water at strengths varying from 3 cc. to 100 cc. to 1 cc. to 1,000 cc. In one day all larvae in the 3 to 100 solution were killed. The pupae gave up adults which died before they could take wing. The weakest strength killed a few larvae in 36 hours.

Pyridine. (Technical, from Eimer and Amend.) The resistance of fully-grown larvae and some pupae of *A. cantator, A. sollicitans* and *C. salinarius* to pyridine in tap-water was tested, at strengths varying from 0.00001 cc. to 1,000 cc. to 0.2 cc. to 1,000 cc. In 1 day all were dead in the 0.2 to 1,000 solution. In 2 days some were dead in the 0.1 to 1,000 solution. In the latter strength some of the pupae gave up adults which, however, perished before they could take wing.

Cresol. (U. S. P., from Eimer and Amend.) The resistance of 2 to 4-mm. *C. pipiens* larvae to cresol in tap-water at strengths varying from 1 cc. to 8,000 cc. to 1 cc. to 50,000 cc. was tested. In 1 day all were dead in the 1 to 30,000 and stronger solutions. In 2 days all were dead in the 1 to 50,000 solution.

Lysol. (A commercial product manufactured by Leher and Fink.) The resistance of 2 to 4-mm. *C. pipiens* larvae to lysol in tap-water in strengths varying from 1 cc. to 8,000 cc. to 1 cc. to 50,000 cc. was tested. In 1 day all were dead in the 1 to 40,000 solution.

Phenol. (100 per cent crude carbolic acid furnished by Eimer and Amend.) The resistance of *C. pipiens* larvae 2 to 4 mm. long to phenol was tested in tap-water at strengths varying from 1 cc. to 1,000 cc. to 1 cc. to 40,000 cc. In 2 days all were dead in the 1 to 30,000 solution.

Mixture of 10 cc. pyridine, 10 cc. xylol, and resin to make 25 cc. The resistance of 2 to 4-mm. larvae of *C. pipiens* to this mixture in tap-water in strengths varying from 1 cc. to 20,000 cc. to 1 cc. to 50,000 cc. was tested. In 1 day all were dead in the 1 to 40,000 solution. This experiment was repeated under the same conditions with the same species of larvae, and in 2 days all were dead in the 1 to 50,000 solution.

Standard Oil samples. During the winter of 1915 the writer requested the Standard Oil Company to prepare an oil which would give good spreading power with strong staying ability. The company responded with three samples; no. 1 and no. 2 were black in color, while no. 3 was a straw yellow. On February 24, 1915, the writer selected three glass dishes, filled to the same height with distilled water. Each dish had about 70 square inches of water surface. Each was treated with 5 cc. of oil. The first received its supply from sample 1, the second from sample 2, and the third from sample 3. Thirty-one days later the oil film of no. 3 was complete, while on both no. 1 and 2 it was broken. Three large glass dishes were then prepared, filled to the same height with water, and each made the recipient of 50 or more 2-mm. larvae of *C. pipiens*. Oil was introduced at the rate of 3 cc. to the square foot. The first was treated with sample 1, the second with no. 2, and the third with no. 3. One day later 8 larvae were alive in no. 1, 10 in no. 2 and none in no. 3.

A test of the lasting power of some of the more promising substances was arranged. Nine wooden wash-tubs were arranged in 4 pairs and a check. One series was filled about half-full of red shale soil.

It is easy to find substances that will kill mosquito larvae very quickly but to get one that will remain effective over a long period seems attended with difficulties. All tubs were filled to the same height with water and were allowed to stand until larvae of *C. pipiens* appeared in each.

Pair no. 1 was then treated with a proprietary substance, known as Khan's mixture, at the rate of 10 gm. to the gallon of water. Pair no. 2 was treated with Standard Oil sample no. 3 at the rate of 1.5 cc. to the gallon, and pair no. 3 with pyridine at the rate of 1.5 cc. to the gallon. Pair no. 4 was treated with the mixture pyridine, xylol and rosin at the rate of 1.5 cc. to the gallon. The tubs were left outdoors throughout the experiment. The results are set forth in table 2.

Table 2

Results of Experiment with Samples of Larvicides

Date	No. 1 Khan's Mixture	No. 2 Standard Oil No. 3	No. 3 Pyridine	No. 4 Pyridine, Xylol and Resin	No.5 No Treatment
9/4	Experiment set up				
9/5	All alive	All alive	All dead except pupae	All dead except pupae	All alive
9/6	Few dead	Few dead	All dead	All dead	All alive
9/7	All dead	All dead	All dead	All dead	All alive
9/10	All dead	All dead	Living *C. pipiens* present	Living *C. pipiens* present	All alive
9/11	All dead	All dead	Living *C. pipiens* present	Living *C. pipiens* present	All alive
9/12	Living *C. pipiens* present	All dead	Living *C. pipiens* present	Living *C. pipiens* present	All alive
9/13	Living *C. pipiens* present	All dead	Living *C. pipiens* present	Living *C. pipiens* present	All alive
9/14	Living *C. pipiens* present	Living *C. pipiens* present	Living *C. pipiens* present	Living *C. pipiens* present	All alive
9/15	Living *C. pipiens* present	Living *C. pipiens* present	Living *C. pipiens* present	Living *C. pipiens* present	All alive

Nitre cake, which is a by-product of gun-cotton manufacture and available in large quantities at a low price was given a pretty thorough trial. So much has been said about this substance as a larvicide that a presentation of certain experiments seems worth while.

Experiments 1, 2 and 3 are designed to determine the minimum dosage for the house mosquito, which was selected as a type of the fresh-water forms.

Experiment 1

OBJECT. To determine the minimum dosage of nitre cake for *Culex pipiens* a series of jars, each containing about 1,000 cc. of water, was set up as follows:

2 gm. of nitre cake in 1,000 cc. of tap-water.
4 gm. of nitre cake in 1,000 cc. of tap-water.
6 gm. of nitre cake in 1,000 cc. of tap-water.
8 gm. of nitre cake in 1,000 cc. of tap-water.
10 gm. of nitre cake in 1,000 cc. of tap-water.
No nitre cake in 1,000 cc. of tap-water.

Twenty-five larvae of *Culex pipiens* were placed in each of the above jars at 12:15 p. m., July 19, 1917. At 8:30 a. m., July 20, 1917, all larvae in the treated jars were dead, while all larvae in the check jar were alive.

Experiment 2

OBJECT. To determine the minimum dosage of nitre cake for *Culex pipiens.* Solutions of nitre cake in tap-water were made up as follows:

50 gm. of nitre cake in 1,000 cc. of tap-water.
25 gm. of nitre cake in 1,000 cc. of tap-water.
10 gm. of nitre cake in 1,000 cc. of tap-water.
1 gm. of nitre cake in 1,000 cc. of tap-water.
No nitre cake in 1,000 cc. of tap-water.

The temperature was 72°. Fifteen larvae of *Culex pipiens* were placed in each jar at 3:30 p. m., July 13, 1917. At 5:15 p. m. the jars were observed with the following results:

All larvae dead in the 25 and 50-gm. solutions.

Five of the younger larvae (second molt) in the 10-gm. solution dead, all others alive.

All alive in the 1-gm. solution and the check.

At 8:30 a. m., July 14, 1917, the larvae dead in all jars except the check.

Experiment 3

OBJECT. To determine the minimum dosage of nitre cake for *Culex pipiens.*

Using the same solution as in experiment 1, two additional dilutions were added as follows:

0.5 gm. of nitre cake in 1,000 cc. of tap-water.
0.25 gm. of nitre cake in 1,000 cc. of tap-water.

Fifty larvae of *Culex pipiens* were placed in each jar at 9:30 a. m., July 14, 1917. Twenty minutes afterward, all larvae were dead in the 50-gm. solution. At 11:00 a. m., July 14, 1917, an examination was made of all jars with the following results:

All larvae dead in the 25-gm. solution.
50 per cent dead in the 10-gm. solution.
10 per cent dead in the 1-gm. solution.
All were alive in the 0.5-gm. and 0.25-gm. and check solutions.

On July 15, 1917, the jars were examined with the following results:

All dead in the 10-gm. solution and above.
5 alive in the 1-gm. solution.
10 alive in the 0.5-gm. solution.
43 alive in the 0.25-gm. solution.
46 alive in the check.

An examination of these jars was made at 9:00 a. m. July 16, 1917, with the following results:

All dead in the 10-gm. solution and above.
One live pupa and 4 pupal shells in the 1-gm. solution.
15 live pupae in the 0.5-gm. solution.
40 larvae and pupae alive in the 0.25-gm. solution.
46 larvae and pupae alive in the check.

Experiments 4 and 5 were designed to determine the minimum dosage for the white-banded salt-marsh mosquito, which was selected as a type of the salt-marsh forms.

Experiment 4

OBJECT: To determine the minimum dosage of nitre cake for *Aedes sollicitans.*

Solutions of nitre cake in salt-marsh creek-water (2% salinity) were made as follows:

25 gm. in 1,000 cc.
10 gm. in 1,000 cc.
1 gm. in 1,000 cc.
0.5 gm. in 1,000 cc.
0.25 gm. in 1,000 cc.
None in 1,000 cc.

Fifty larvae of *Aedes sollicitans* were placed in each jar at 10:45 a. m., July 14, 1917. At 12:15 p. m. the following results were observed:

75 per cent dead in the 25-gm. solution.
10 per cent dead in the 10-gm. solution.
All alive in remaining solutions.

At 12:15 p. m., July 15, 1917, the jars were again examined with the following results:

All dead, even pupae, in 25-gm. solution.
All larvae dead, 2 live pupae, in 10-gm. solution.
50 per cent dead in 1-gm. solution.
15 per cent dead, many live pupae, in 0.5-gm. solution.
All alive or transformed to pupae in 0.25-gm. solution.
All alive in check.

On July 16, 1917, at 9:00 a. m., the jars were again examined, with the following results:

All dead in 25-gm. solution.
2 live pupae in 10-gm. solution.
10 live larvae, many empty pupal shells and live pupae in 1-gm. solution.
No increase in mortality in solutions of lower strength.

Experiment 5

OBJECT: To determine the minimum dosage of nitre cake for *Aedes sollicitans* in saline water.

Solutions of nitre cake in salt-marsh creek-water.

A series of jars were prepared as follows:

0.5 gm. of nitre cake in 1,000 cc. of water testing 7 per cent salinity.
1 gm. of nitre cake in 1,000 cc. of water testing 7 per cent salinity.
2 gm. of nitre cake in 1,000 cc. of water testing 7 per cent salinity.
4 gm. of nitre cake in 1,000 cc. of water testing 7 per cent salinity.
6 gm. of nitre cake in 1,000 cc. of water testing 7 per cent salinity.
8 gm. of nitre cake in 1,000 cc. of water testing 7 per cent salinity.
10 gm. of nitre cake in 1,000 cc. of water testing 7 per cent salinity.
No nitre cake in 1,000 cc. of water testing 7 per cent salinity.

At 5:30 p. m., August 3, 1917, 50 half-grown *sollicitans* were placed in each jar. At 9:30 a. m., August 4, 1917, the jars were examined with the following results:

All alive in check solution.
All alive in 0.5-gm. solution.
All alive in 1-gm. solution.
2 dead in 2-gm. solution.
50 per cent dead in 4-gm. solution.
All dead except one in 6-gm. solution.
All dead in 8-gm. solution.
All dead in 10-gm. solution.

At 10:30 a. m., August 6, 1917, the following results were noted:

25 per cent dead in 0.5-gm. solution.
50 per cent dead in 1-gm. solution.
82 per cent dead in 2-gm. solution.
90 per cent dead in 4-gm. solution.
All dead in 6, 8 and 10-gm. solutions.
All alive in check.

Experiment 6 was undertaken to determine the persistence of nitre cake in fresh water. It was not thought advisable to make a similar test in salt water because the salt pools are always subject to disturbance by the tide.

Experiment 6

OBJECT. To determine the persistence of nitre cake as a larvicide.

A large wooden tub containing a layer of mud and approximately 40 liters of water in which larvae of *Culex pipiens* were present was treated with 400 gm. of nitre cake, at 12:30 p. m., July 19, 1917. A check tub of the same dimensions with the same contents was left untreated. Examinations were made 30 hours later. All larvae in the treated tub were dead and none of those in the untreated tub were dead. Some of the pupae were destroyed in the treated tub and some had given up adults.

On Friday, August 3, 1917, a number of *Culex pipiens* larvae were placed in the treated tub. Twenty-four hours later all these larvae were dead. No oviposition took place in the water of the treated tub from the time of treatment, July 19 to August 9, 1917. It thus appears that 1 gm. of nitre cake to 1,000 cc. of water is barely sufficient to destroy the larvae of *Culex pipiens* in 2 days' time, but that stronger solutions (1 gm. of nitre cake to 100 cc. of water) destroy the species readily and remain effective for 21 days or longer It thus appears that 6 gm. of nitre cake to 1,000 cc. of water testing 7 per cent salinity is necessary to destroy the larvae of *Aedes sollicitans* and that 3 days are required to accomplish this result.

The bearing of these results upon the practical use of nitre cake as a larvicide needs elucidation. In view of the fact that a diminution in the strength of the solution results in loss of efficiency, nitre cake should not be used as a larvicide except in pools and bodies of water that have no outlet. In view of the cost of distributing the material, it would seem unwise to use the minimum strength. Enough should be put in to insure not only prompt destruction of the larvae but a reasonable continuance of that effect. Considerable time is required for dissolving the nitre cake, and its distribution through the water is relatively slow. Throwing the material into the pool in a cake or even in ground form is likely to result in unsatisfactory results because of the slowness with which the material will dissolve and the slowness with which the dissolved material will distribute. These difficulties are great and need to be overcome before its use will be practical.

Canal Zone Larvicide

COMPOSITION

In the course of their work in Panama, Le Prince and Orenstein[13] developed a larvicide, the active principal of which was carbolic

[13]Le Prince, J. A., and Orienstein, A. J., 1916, Mosquito Control in Panama.

acid. It was made up of resin, 150 to 200 pounds; soda, 30 pounds; and carbolic acid, 150 gallons. This forms a black liquid resin soap. It is said that this material emulsifies readily with fresh water but not with alkaline or brackish water. It is specified that the phenol content of the crude carbolic acid should be uniform and not less than 15 per cent. It is further specified that the crude carbolic should have a specific gravity of 0.97.

METHOD OF MAKING

The mixture is made under heat as follows:

One hundred and fifty gallons of the carbolic acid is heated in a steel tank fitted with a steam coil. When the acid is steaming hot, 200 pounds of powdered resin is added and the mixture continuously stirred by means of a paddle agitator, until complete solution is effected. Thirty pounds of caustic soda (sodium hydroxide) is dissolved in 6 gallons of water, and this is added to the resin-carbolic acid mixture. The heating and stirring is kept up for about 5 minutes, and then a sample of the product is withdrawn, and poured into water. If complete and rapid emulsion results, the larvicide is ready and is withdrawn from the mixing tank into shipping drums. If emulsion does not occur, or is incomplete, the heating is continued until a sample emulsifies satisfactorily.

ADVANTAGES

Le Prince and Orenstein[14] state the advantages and disadvantages of this material as follows:

The advantages of this phenol-resin soap larvicide are:

1. *High toxicity to mosquito larvae.* A 1 to 5,000 emulsion kills full-grown *Anopheles* larvae in from 3 to 10 minutes.

2. *Concentration.* Being effective for practical use in a 1 to 5,000 emulsion, only a relatively small quantity of the larvicide need be transported to a given body of water.

3. *Uniformity of toxic power.* This product, when carefully made, is uniform in toxicity.

4. *Simplicity of composition.* The manufacture of this larvicide requires neither complicated apparatus nor highly skilled labor.

5. *Low toxicity to higher animals.* It is practically harmless in ordinary dosage or in dilution, to cattle, poultry, etc.

6. *Rapidity of toxic action.* When used in the field, it killed all *Anopheles* larvae and pupae in 10 to 20 minutes.

7. *Cheapness of the product.* In Panama, the cost is about 18 cents a gallon.

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[14]Le Prince, J. A., and Orenstein, A. J., 1916, Mosquito Control in Panama.

8. *Absence of danger from fire.* The concentrated larvicide is inflammable, but not easily ignited. In dilution it is not inflammable.

9. *It is useful in the rapid determination of the presence of mosquito larvae* and kills those at rest embedded in the mud.

10. In addition to its toxicity for mosquito larvae the phenol-resin larvicide is also *highly toxic to protozoa and algae,* as well as most of the varieties of the common grasses encountered in Panama. The algacidal and herbicidal properties of this larvicide are of frequent use in mosquito eradication.

DISADVANTAGES

The disadvantages of this larvicide are:

1. *It does not emulsify and is inert in brackish water.* This is a serious disadvantage because many *Anopheles* breed in brackish water and *Culex* breed in salt-water marshes and pools. This defect, however, is shared by all the commercial larvicides tested on the Isthmus.

2. *The pure larvicide deteriorates* upon exposure to the air and must be kept in drums, barrels, and other tightly closed containers.

3. *It rapidly loses its toxicity after mixing with water containing algae and other organic matter.* After 24 hours its toxicity is so far diminished that it is practically non-toxic from the standpoint of field practice.

The ideal mosquito larvicide should in addition to possessing all the desirable qualities of the phenol-resin soap described above, possess none of the disadvantages enumerated. We have not yet found such a product, either on the market or by experimenting with various mixtures.

The toxic action of the phenol-resin larvicide upon mosquito larvae is probably due to the action of its phenol content upon the protoplasm of the larvae, probably intensified by the fact that the phenol is in emulsion.

Conclusions

The preceding account of larvicides does not pretend to recount the really immense number of substances that have been tried but merely to bring out the experience of certain organizations that have been engaged in practical mosquito control on a large scale. It thus appears (so far as the writer's knowledge goes, experimental and practical work elsewhere but not reported in this bulletin seems to be in substantial agreement) that no larvicide has yet been devised which covers as wide a field or is as practical under all conditions as is petroleum oil. It is not for a moment denied that certain larvicides may not fit specific cases better than oil but it is maintained that they take a place in mosquito control as adjuncts and supplements to petroleum oil as larvae killers.

The best petroleum oil is one which readily forms a complete homogenous film when applied to the water surface by a small portable sprayer, and one which remains effective for at least two weeks, or better still for one month. In the experiments above recorded it

was clearly shown that Standard Oil sample 3 was decidedly superior. It is, therefore, possible to secure a special mosquito oil which is more effective than the usual fuel oil.

Without doubt there are occasions when persistence of the larvicide is a decided detriment and in such instances a light rapidly evaporating substance such as gasoline can be employed. The work, which specific larvicides seem fitted to do, is indicated by the following table:

Nitre Cake—Fire barrels, tubs and in some cases permanent pools.
Canal Zone—Shallow temporary pools where killing must be quick, flooded cellars where wall staining is a serious consideration, pools in which the irritating mosquito is breeding.
Mosquito Oil—All other water surface which cannot be reached by drainage, filling or fish.

Permanent Work

Under this head we have those operations of draining, filling, and grading which eliminate mosquito breeding by the removal of the water in which breeding occurs or the elimination of its stagnant condition by the establishment of circulation. Only by accomplishing the largest amount of this type of work, which the temporary suppression and the funds available render possible, can real progress in mosquito control be made. Every mosquito-fighting organization should strive to accomplish as much of this work as possible.

Filling and grading, especially the former, involve very large expenditures for the results accomplished, but both have the merit of requiring a very small maintenance in succeeding years. Because of the cost, only a small amount of this type of work can be done. Special conditions, such as an abundance of ash-garbage seeking-place for disposal, may make it possible to do a relatively large amount of this work. All opportunities of this kind should be utilized.

In drainage, however, the mosquito-fighting organization will find it possible to eliminate mosquito breeding on a large scale. Drainage for mosquito control is neither so thorough nor so expensive as drainage for agricultural or urban development. It is sufficient to remove the water from the surface of the soil or to place it in rapid motion between clean banks. It is necessary to establish sufficient drainage to insure that water from the maximum rainfall will be off the surface within one week's time or less, and it is best to pro-

A

B

C

Fig. 119. Transformation of mosquito-breeding swamp into a lake surrounded by a city park. A, Original conditions; B, first cleaning; C, second cleaning and deepening. (See fig. 120 for completed work).

Fig. 120. Final stage of operations shown in figure 119.

vide, in case the outlet cannot be large enough to insure a prompt run-off, for such a lowering of the water table that at least 6 inches

A

B

Fig. 121. Drainage of an open swamp. A, before; B, after.

of dry soil will be formed in the course of a few weeks' operation of the ditching systems.

The type of ditch cut will depend upon the soil, the fall that can be obtained, and the funds available to do the work. Without doubt the best ditch is made of tile or other drainage pipe of ade-

Fig. 122. Drainage of large woodland swamp. A, condition before; B, condition after.

quate size laid well under ground. Some soils are too soft to allow this pipe to remain in place. In some cases the fall which may be had is so slight that covered drains will fill up quickly. In many cases the installation of covered pipes is impracticable from the

standpoint of cost. In instances where covered pipes cannot be laid the open ditch must be resorted to. Size and depth will be determined by the water which it must carry and the speed at which the

A

B

Fig. 123. Drainage of a woodland pool. A, before; B, after.

Fig. 124. Upland ditching of various types.

A

B

Fig. 125. Attempt to use dynamite in woodland swamp ditching. A, before blasting; B, after blasting.

water will travel, for, obviously the more swiftly the water will flow the smaller the ditch may be made and yet carry off the necessary amount of water. The slope of the banks will depend upon the nature of the soil, for they must not cave in and block the drainage. Under the best conditions much maintenance will be required in succeeding years.

All the preceding discussion of ditching assumes that there is sufficient fall to render the continuous movement of water in one direction possible. Without doubt, as is usually the case, instances will be found on salt marshes where such movement cannot be provided for. In such cases the water may be removed from the surface by ditches and kept moving by introducing a water supply at their heads.

The planning of drainage systems of various sorts is an engineering problem and must be handled in that way.

The financing of drainage operations may prove a very great burden or indeed may be impracticable, but much can be done by securing the cooperation and a large amount of the funds from the land-owners. The mosquito-fighting organization should keep a keen lookout for land-owners who desire to improve their lands for agricultural purposes and should in every possible way encourage any effort.

Let no year pass in which an appreciable percentage of permanent filling, grading and drainage work is not done and in the course of a few years the protected area will reach a point where adequate protection can be given for a sum merely sufficient to provide for a minimum of temporary work and the maintenance of the permanent work. The higher the percentage of total breeding places that have been permanently eliminated, the smaller will be the temporary work necessary to give the people living in protected areas adequate protection.

Brief History of Mosquito Control in New Jersey and Adjacent Territory

As a net result of an investigation made concerning the beginnings of anti-mosquito work in New Jersey, it seems that a number of persons, among whom should be included particularly Dr. John B. Smith and Spencer Miller, were giving serious thought to the problem previous to the year 1900. In 1900 Dr. Smith secured from the director of the New Jersey Agricultural Experiment Stations a small sum of money for a preliminary investigation of the problem.

On June 27, 1901, Dr. Smith sent out the following communication to the various boards of health in the state:

It is my intention to devote some time during the present season to an investigation of the mosquito question as it exists at the present time in New Jersey. The recently established connection between malaria and mosquitoes makes this matter important from the sanitary standpoint and gives it a direct bearing upon the health of the community. For this reason I have asked the cooperation of the State Board of Health and have received from its secretary, Dr. Henry Mitchell, cordial assurance of support.

It is necessary, however, to make my work complete, that I should also enlist the cooperation of local boards throughout the state; therefore I beg you for information on the following points:

1. Is "malaria" a prevalent disease within your jurisdiction; i. e. are the cases at all numerous?

2. If cases are numerous, are they localized, or are they scattered throughout the community?

3. Is one case apt to be followed by others close by?

4. Are mosquitoes numerous in your jurisdiction, and if so, are they generally spread or is one part of the district more infested than others?

5. Have you observed any relation between the abundance of mosquitoes and the prevalence of malaria?

6. If mosquitoes are plentiful can you tell where they breed?

7. Will you send me from time to time specimens of the troublesome mosquitoes in your jurisdiction? I will supply as many vials as are needed, and will be glad to give whatever information is desired as to methods of collecting and preserving.

8. Any further information bearing on the above matters is desired and will be appreciated.

It may be added that the information obtained will not be published in such a way as to prejudice any particular locality; but is necessary to establish facts and relations. It is also to be used as a basis for recommending measures to mitigate or locally abolish the mosquito pest.

Awaiting your early and, I hope, full reply, I am,

Very truly yours,

JOHN B. SMITH,

Entomologist to the Experiment Station and State Entomologist.

In the same year the South Orange Improvement Association, under the leadership of Spencer Miller, initiated a local campaign against the pests and secured Dr. L. O. Howard, chief of the Bureau of Entomology, to lecture in South Orange on that subject on May 16, 1901. Following this lecture the South Orange Improvement Association carried on a campaign throughout that season and each season following until the work was taken up on a broader basis.

In the meantime interest in mosquito control had made its appearance among the residents of the north shore of Long Island. This interest seems largely to have been stimulated by the work of Henry Clay Weeks and to have involved William J. Matheson, Paul D. Gravath, C. B. Davenport and others.

For the sake of clearness it seems to be advisable to give a separate account of the activities of each of several groups, all of which were working in one way or another along lines of mosquito suppression.

Anti-mosquito Work of the New Jersey State Agricultural Experiment Station from 1902 to 1911, inclusive

Sufficient progress was made by Dr. Smith with the appropriation of 1900 to enable him to induce the Legislature of the state in the year 1902 to pass an act appropriating the sum of $10,000 for a study of the mosquito problem. The language of the act is submitted herewith:

Chapter 98, Laws of 1902

An Act to provide for an investigation and report by the New Jersey Agricultural Experiment Station upon the mosquito problem in its relation to the sanitary, agricultural and other interests of the state.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. The New Jersey Agricultural Experiment Station be and the same is hereby empowered and directed to investigate and report upon the mosquitoes occurring within the state, their habits, life history, breeding places, relation to malarial and other diseases, the injury caused by them to the agricultural, sanitary and other interests of the state, their natural enemies, and the best methods of lessening, controlling or otherwise diminishing the numbers, injury or detrimental effect upon the agricultural, sanitary and other interests of the state.

2. The sum of $10,000 is hereby appropriated to the New Jersey Agricultural Experiment Station to be applied to and expended for the purpose mentioned in section 1 of this act; such expenditures to be made and accounted for in the same manner as are the other moneys appropriated to said station.

3. This act shall take effect immediately.

Approved April 3, 1902.

Unfortunately the appropriation committee failed to provide the money and the work was continued during the following summer only through the interest of Governor Murphy, who set aside from his emergency fund the sum of $1,000 for this purpose. The appropriation committee of the 1903 Legislature provided the funds contemplated in 1902.

With the necessary funds in hand Dr. Smith planned and carried out a very careful study of the structural characters, the life history and habits, and methods of controlling the principal species. He proved for the first time that salt-marsh-bred species migrated for long distances over the upland, reaching points more than 30 miles away in large numbers and infesting seriously more than one-half the

state's land surface and annoying very seriously nearly three-fourths of her population. These and other facts he embodied in a large special report of the New Jersey Agricultural Experiment Station published in 1904.

With facts derived by this study in hand, the State Legislature was induced to pass an act in 1905 providing for state aid to communities that cared to spend their own funds in salt-marsh drainage for mosquito control. The wording of this act is presented herewith:

Chapter 80, Laws of 1905

An Act to provide a method for locating and destroying mosquito-breeding areas, authorizing appropriations for said purposes and providing state aid for freeing salt-marsh areas from mosquitoes.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. It shall be lawful for the mayor, or executive officer, or the board of health of any city, borough, incorporated town, village, or the governing body or board of health of any township or county to make request in writing to the director of the Agricultural Experiment Station in this state, or to the person appointed by said director for the purposes of this act, to investigate, or cause to be investigated, the source of breeding places of mosquitoes which may or do infest said city, borough, incorporated town, village, township or county; and it shall be the duty of such director, or the person appointed by him, as soon as may be after such application is made, to investigate, or cause to be investigated, the source or breeding places of such mosquitoes, and he shall, as soon thereafter as possible, report to the officer or body making such application the results of the investigation made, and also the measures that should be adopted to destroy such breeding places or render them free from future mosquito breeding.

2. If such investigation shows that the sources or breeding places of the mosquitoes complained of are wholly within the jurisdiction of the city, borough, incorporated town, village, township or county from which the application is made, a report shall be made to the officer or body requesting the investigation, and if such request does not come from a board of health, a copy shall also be forwarded to the board of health of such applying city, borough, incorporated town, village, township or county, which report shall specify in such detail as is possible such breeding places as may be abolished by such board under the powers conferred upon it by the laws relating to such boards; if the investigation shows that the mosquitoes complained of breed wholly or in part at a point or points without the jurisdiction of the city, borough, incorporated town, village, township or county from which the application is made, a copy of the report showing this result shall also be sent to the board or boards of health in the jurisdiction or jurisdictions where such breeding places are found, or if there be no organized board of health in any such jurisdiction, then the copy shall be sent to the mayor or executive officer of said city, borough, incorporated town, village, or the governing body of such township or county; the copy of the report above pro-

vided for, when sent to any officer, board of governing body or any jurisdiction other than the one from which the request for the investigation originated, shall be accompanied by a statement giving the origin of the request, the reasons leading to the conclusion that the breeding places for mosquitoes lying within the jurisdiction to which the report is sent, are supplying specimens found in the neighboring jurisdiction, and submitting the measures that should be taken to abolish these breeding places.

3. Whenever an investigation made as aforesaid shall disclose the fact that the mosquitoes infesting the community and causing the nuisance complained of are those breeding on the salt-marsh areas within the jurisdiction of any city, borough, incorporated town, village, township, or county from which the application is made or adjacent thereto, a copy of the report shall be sent to the board or boards of health of the municipality or municipalities in which the breeding places are situated, attaching statements specifying the localities affected by the marsh-breeding areas, the extent of the dangerous area, the character of the work necessary to prevent further mosquito breeding, and the probable cost of the work required in each municipality. It shall be lawful for the governing body of any municipality above mentioned, upon the written request of the board of health of said municipality, to appropriate, in the same manner as other appropriations are made, 75 per cent of the sum required to complete the work aforesaid; whenever such appropriation is made and is available, said board of health shall certify this fact to the director of the Agricultural Experiment Station, who may, out of the money appropriated by the state for this purpose, together with the appropriation of such municipality so certified as available, complete the work; *provided,* not more than $500.00 from said state-aid appropriation shall be expended in any one municipality in any one year.

4. Whenever it appears from the report made to any officer or body making application for an investigation, that the sources or breeding places of the mosquitoes complained of are on the salt marshes, wholly or in part without the jurisdiction of the city, borough, incorporated town, village, township or county from which the application is made, it shall, nevertheless, be lawful for the governing body of any such municipality to appropriate in the same manner as other appropriations are made, such sum or sums as may be deemed necessary to assist the municipality in which the breeding places actually occur in securing the amount necessary to obtain the state aid conditioned in section 3 of this act; *provided,* that no matter how many municipalities contribute, the sum limited in section 3 shall not be exceeded in any one municipality.

5. All sums contributed or appropriated under authority of this act shall be paid to the treasurer of the municipality in which the work is to be done, and the funds shall not be deemed available until the entire amount contributed or appropriated shall be actually in the hands of such treasurer; payments shall be made by such treasurer in the same manner as other bills against the municipality are paid, but no bill for work done shall be paid unless it is accompanied by a certificate from the director of the Agricultural Experiment Station or the person designated by him to carry out the purposes of this act, stating that the work is satisfactory and effective for the purpose intended.

6. The sum of $2500.00 is hereby appropriated to the Agricultural Experiment Station for the fiscal year ending October 31, 1905 and the sum of $3500.00 is hereby appropriated to said station for the fiscal year ending October 31, 1906, to defray the cost of executing this law and of making such investigations and experiments as may be necessary to carry out its intent and purpose, and the further sum of $10,000.00, $4,000.00 to become available during the fiscal year ending October 31, 1905, and $6,000.00 for the fiscal year ending October 31, 1906, or so much thereof as is needed, is hereby appropriated to said station to be used in carrying out the provisions for state aid.

7. This act shall take effect immediately.

Approved March 31, 1905.

Local authorities with one exception, Elizabeth, utterly failed to take advantage of this law and all the money appropriated, with the exception of $1,000 which was spent on the Elizabeth marsh, was returned to the state treasury.

During 1905 Dr. Smith caused a rapid survey of the entire salt marsh to be made and calculated on the basis of that work that the necessary initial drainage could be completed by the expenditure of $350,000. With the facts in hand the State Legislature enacted a law charging the New Jersey Agricultural Experiment Station with the duty of draining the salt marsh with such portions of the $350,000 as the appropriations committee could be induced to give from year to year. The text of this act is presented herewith:

Chapter 134, Laws of 1906

An Act to provide for locating and abolishing mosquito-breeding salt-marsh areas within the state, for assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. It shall be the duty of the director of the State Experiment Station, by himself or through an executive officer to be appointed by him to carry out the provisions of this act, to survey or cause to be surveyed all the salt-marsh areas within the state, in such order as he may deem desirable, and to such extent as he may deem necessary, and he shall prepare or cause to be prepared a map of each section so surveyed, and shall indicate thereon all the mosquito-breeding places found on every such area, together with a memorandum of the method to be adopted in dealing with such mosquito breeding places, and the probable cost of abolishing the same.

2. It shall be the further duty of said director, in the manner above described, to survey at the request of the board of health of any city, town, township, borough or village within the state, to such extent as may be necessary, any fresh-water swamp or other territory suspected of breeding malarial or other mosquitoes, within the jurisdiction of such board, and he shall prepare a map of such suspected area, locating upon it such mosquito-

breeding places as may be discovered and shall report upon the same as hereinafter provided in section 8 of this act. Requests as hereinafter provided for in this section may be made by any board of health within the state, upon its own motion, and must be made upon the petition, in writing, of ten or more freeholders residing within the jurisdiction of any such board.

3. Whenever, in the course of a survey made as prescribed in section 1 of this act, it is found that within the limits of any city, town, township, borough or village, there exist points or places where salt-marsh mosquitoes breed, it shall be the duty of the director aforesaid, through his executive officer, to notify, in writing, by personal service upon some officer or member thereof, the board of health within whose jurisdiction such breeding places or points occur, of the extent and location of such breeding places, and such notice shall be accompanied by a copy of a map prepared as prescribed in section 1, and of the memorandum stating the character of the work to be done and its probable cost, also therein provided for. It shall thereupon become the duty of the said board, within 20 days from the time at which notice is served as aforesaid, to investigate the ownership, so far as ascertainable, of the territory on which the breeding places occur, and to notify the owner or owners of such lands, if they can be found or ascertained, in such manner as other notices of such boards are served, of the facts set out in the communication from the director, and of the further fact that under chapter 68 of the laws of 1887, as amended in chapter 119 of the laws of 1904, any water in which mosquito larvae breed is a nuisance and subject to abatement as such. Said notice shall further contain an order that the nuisance, consisting of mosquito-breeding pools, be abated within a period to be stated, and which shall not be more than 60 days from the date of said notice, failing which the board would proceed to abate, in accordance with the act and its amendments above cited.

4. In case any owner of salt-marsh lands on which mosquito-breeding places occur and upon whom notice has been served as above set out, fails or neglects to comply with the order of the board within the time limited therein, it shall be the duty of said board to proceed to abate under the powers given in section 13 and 14 of the act and its amendments cited in the preceding section, or, in case this is deemed inexpedient, it shall certify to the common council or other governing body of the city, town, township, borough, or village, the facts that such an order has been made and that it has not been complied with, and it shall request such council or other governing body to provide the money necessary to enable the board to abate such nuisance, in the manner provided by law. It shall thereupon become the duty of such governing body to act upon such certificate at its next meeting and to consider the appropriation of the money necessary to abate the nuisance so certified. If it be decided that the municipality has no money available for such purpose, such decision shall be transmitted to the board of health making the certificate, which said board shall thereupon communicate such decision forthwith to the director of the Agricultural Experiment Station or his executive officer.

5. If, in the judgment of the director aforesaid, public interests, will be served thereby, he may set aside out of the moneys appropriated by this act such an amount as may be necessary to abate the nuisance found existing and to abolish the mosquito-breeding places found in the municipality which has declared itself without funds available as prescribed in the preceding

section. Notice that such amount has been set aside as above described shall be given to the board of health within whose jurisdiction such mosquito-breeding places are situated, and said board shall thereupon appoint some person designated by said director or his executive officer a special inspector of said board for the sole purpose of acting in his behalf in abating the nuisance found to be existing, and all acts and work done to abate such nuisances and to abolish such breeding places shall be done in the name of and on behalf of such board of health.

6. If, in the proceeding taken under section 4 of this act, the common council or other governing body of any municipality appropriate to the extent of 50 per centum or more of the money required to abate the nuisance and to abolish the mosquito-breeding places within its jurisdiction, it shall become the duty of said director of the Agricultural Experiment Station to set aside out of the moneys herein appropriated such sum as may be necessary to complete the work, and in all cases preference shall be given, in the assignment of moneys herein appropriated, to those municipalities that contribute to the work and in the order of the percentage which they contribute; those contributing the highest percentage to be in all cases preferred in order.

7. In all cases where a municipality contributes 50 per centum or more of the estimated cost of abolishing the breeding places for salt-marsh mosquitoes within its jurisdiction, the work may be done by the municipality as other work is done under its direction, and the amount set aside as provided in section 6 may be paid to the treasurer or other disbursing officer of such municipality for use in completing work; but no payment shall be made to such treasurer or other disbursing officer until the amount appropriated by the municipality has been actually expended, nor until a certificate has been filed by the director or his executive officer stating that the work already done is satisfactory and sufficient to obtain the desired result, and that the arrangements made for its completion are proper and can be carried out for the sum awarded.

8. In all investigations made under section 2 of this act, the report to be made to the board of health requesting the survey shall state what mosquitoes were found in the territory complained of, whether they are local breeders or migrants from other points, and, in the case of migrants, their probable source, whether the territory in quesetion is dangerous or a nuisance because of mosquito breeding, the character of the work necessary to abate such nuisance and abolish the breeding places, and the probable cost of the work. Said board of health must then proceed to abolish the breeding places found under the general powers of such boards, but if it shall appear that the necessary cost of the work shall equal or exceed the value of the land without increasing its taxable value, such board may apply to the director aforesaid, who may, if he deems the matter of sufficient public interest, contribute to the cost of the necessary work provided that not more than 50 per centum of the amount shall be contributed in any case and not more than $500.00 in any one municipality.

9. All moneys contributed or set aside out of the amount appropriated in this act by the director of the Agricultural Experiment Station in accordance with its provisions shall be paid out by the comptroller of the state upon the certificate of said director that all the conditions and requirements of

this act have been complied with, and in the case provided for in section 5 payments shall be made to the contractor upon a statement by the person in charge of the work, as therein prescribed, attested by said director, showing the amount due and that the work has been completed in accordance with the specifications of his contract.

10. For the purpose of carrying into effect the provisions of this act, the said director of the State Agricultural Experiment Station shall have power to expend such amount of money, annually, as may be appropriated by the Legislature; *provided,* that the aggregate sum appropriated for the purposes of this act shall not exceed $350,000.00. The comptroller of the state shall draw his warrant in payment of all bills approved by the director of the State Experiment Station, and the treasurer of the state shall pay all warrants so drawn to the extent of the amount appropriated by the Legislature.

11. This act shall take effect November 1, 1906.

Approved April 20, 1906.

Beginning in 1906 the drainage of the salt marsh for mosquito control went forward on the basis of the act last quoted until its efforts were supplemented in the year 1912 by an act which is known as Chapter 104, Laws of 1912.

Anti-mosquito Work of Local Associations

The local campaign against mosquitoes in South Orange, under the leadership of the South Orange Improvement Association, beginning in 1901 continued steadily each year until it was taken over by the Essex County Mosquito Extermination Commission and carried on under the provisions of Chapter 104, Laws of 1912.

In April, 1902, another anti-mosquito movement was started in Elizabeth, Union County. There 16 citizens subscribed $25.00 each for field work toward overcoming the pest. This was spent in oiling and draining a small portion of meadow at the foot of Schiller Street.

In April, 1903, the Elizabeth Board of Health, with a $1,000 appropriation, dug 40,000 feet of ditches, draining some 190 acres. These were the first ditches to be dug by machine.

The next to fall in line was Newark. Active work, though, was not started until 1904, the Common Council that year voting the sum of $5,000 for that purpose, having refused an appropriation the previous year.

On May 5, 1903, the Newark City Board of Health appointed one of its members, Frederick W. Becker, M. D., a committee to inquire into the question of mosquito extermination.

Several reports were submitted. On July 7, 1903, Dr. John B. Smith read a paper on mosquito elimination, and also exhibited a map

of the Newark meadows, made for the occasion, on which he showed where most breeding occurred. A week later, the following notice was sent out:

Newark, N. J., July 14, 1903.

Dear Sir:—Your presence is requested at a meeting to be held in the rooms of the Newark Board of Health, 880 Broad Street, on Friday evening, July 17, 1903 at 8:30 o'clock, for the purpose of discussing the problem of mosquito extermination.

There will be present gentlemen from the boards of health representing the various communities within our mutual sphere of interest. As only through hearty cooperation may we expect relief from this pest, it is earnestly hoped that you will be present.

Respectfully,

F. W. BECKER, M. D.

This was the first attempt made in New Jersey for the extermination of the mosquito through cooperative endeavor.

Pursuant to this notice a meeting was held with representatives from Orange, Harrison, Summit, Springfield, Bloomfield, South Orange, Irvington, Montclair, East Orange, Belleville, Vailsburg, Millburn, Elizabeth and Newark. It was decided that a temporary organization be formed with a view of making it permanent. Dr. Becker of Newark was elected temporary chairman. The following were appointed the Committee on Organization:

Dr. F. W. Becker, Newark.
S. P. Gilbert, Bloomfield.
H. F. Parker, Montclair.

On July 24 a permanent organization, known as the Conference Committee on Mosquito Extermination was formed and the following officers were elected:

President, Dr. F. W. Becker, Newark.
Vice-President, John Malone, Harrison.
Secretary and Treasurer, Louis J. Richards, Elizabeth.

A Legislative Committee was appointed at this meeting consisting of the president; Dr. T. N. Gray, chairman; Spencer Miller, C. E.; J. B. Thompson; S. P. Gilbert and Louis J. Richards, secretary.

That winter this committee drew up a bill which was introduced in the Assembly in February, 1904, by Hon. Edward D. Duffield, Assemblyman from Essex County. It was passed and signed by Governor Stokes on March 28, 1904.

This is known as the Duffield Act, Chapter 119, Laws of 1904. It is an important mile-stone in the progress of our work, and no occasion has since arisen to change it materially.

Fig. 126. Members and guests of the conference committee on mosquito extermination inspecting Newark meadows recently ditched June 2, 1905.

At a meeting of the Conference Committee on Mosquito Extermination, held on May 19, 1904, the Legislative Committee reported that the anti-mosquito clause had been passed by the Legislature, and was now a law and a part of the General Health Act.

The following gentlemen composed the original Conference Committee on Mosquito Extermination:

New Brunswick, Dr. John B. Smith.
Orange, Herbert Richards; William Schleuer.
Harrison, John Malone; John J. Scanlon.
Summit, T. J. Scott.
Springfield, J. L. Denman; Dr. Stiles.
Bloomfield, Seymour P. Gilbert.
Newark, Dr. F. W. Becker; D. D. Chandler.
Arlington, John B. Thompson.
South Orange, Spencer Miller, C. E.
Irvington, J. K. Clickenger; Hugh Winkler.
Montclair, Horatio F. Parker.
East Orange, E. M. Brewster; Dr. T. N. Gray.
Belleville, Dr. John F. Condon.
Vailsburg, Dr. P. R. Davenport.
West Orange, Mr. Grady.
Glen Ridge, John A. Brown; John B. Smith.
Plainfield, L. R. Thurlow.
Kearny, John B. Thompson.
Elizabeth, Louis J. Richards.

On October 8, 1905, Dr. T. N. Gray took the presidency, succeeding Dr. Becker.

In 1910, the name of the association was changed to the North Jersey Mosquito Extermination League. Dr. N. Elliot was secretary, but his minutes have been lost. He resigned on May 20, 1912, Louis J. Richards taking his place.

Anti-Mosquito Work of the North Shore Improvement Association of Long Island

This association with offices at 49 Wall Street, New York City, published on October 1, 1902, an account of anti-mosquito work done in the association's territory by Frank E. Lutz and William W. Chambers, in which it was shown that a vast amount of interest had been stimulated and that the mosquito problem in that section of Long Island had received a pretty thorough investigation. The work of this association appears to have lagged as the years went by until 1914, when a bill was enacted by the Legislature of the State of New York creating the Nassau County Mosquito Extermination Commission.

Anti-Mosquito Work of the American Mosquito Extermination Society

In 1903 there was formed in New York a National Society for the suppression of the mosquito pest, known as the American Mosquito Extermination Society, under the leadership of William J. Matheson as president, and Henry Clay Weeks as secretary. A convention was held in December of that year and later a little folder entitled "Mosquito Brief of the American Mosquito Extermination Society" was published. A summary of most of the main facts concerning the mosquito problems as we know them today is set forth in this little folder and the publicity which the movement received did much toward making the layman understand the nature of the problem. After a comparatively short career this society ceased to be an active factor in mosquito work.

Anti-Mosquito Work in Greater New York

About the year 1904 Dr. Alvah H. Doty, then health officer of the Port of New York became vitally interested in the problems of mosquito control within the limits of the city and led a movement which resulted in the establishment of a large amount of salt-marsh drainage in Staten Island and about the City of New York itself. After Dr. Doty ceased to be connected with this phase of the city work the work of mosquito control lagged for a number of years. In the year 1915, under the leadership of Dr. Haven Emerson, then health officer of the city of New York, an appropriation of $150,000 was made for the purpose of finishing the drainage of the salt marshes within the limits of Greater New York. This work was carried on under the immediate direction of Eugene Winship, sanitary engineer of the Department.

Unification of Anti-Mosquito Work in New Jersey

It will be remembered that since 1906 the New Jersey Agricultural Experiment Station has been steadily engaged in installing as large an amount of salt-marsh drainage as the funds, which the Legislature saw fit to appropriate annually, would permit. It will also be remembered that the various local campaigns have been steadily continued and extended. All this work in the year 1912 crystallized in the form of a bill which passed the Legislature under the caption of Chapter 104, Laws of 1912. This act is known as the County Mosquito Extermination Commission Law and provides for the appointment of a non-paid mosquito commission in

every county in the state. The duty of this commission is to formulate plans, secure funds, build and operate an organization for the suppression of the mosquito pest.

Under the provisions of this law the appointing power was lodged in the hands of the Supreme Court judges and the New Jersey Agricultural Experiment Station was designated as the centralizing and general directing agency.

The language of this important act is submitted herewith:

Chapter 104, Laws of 1912

An Act for the establishment of county mosquito extermination commissions and to define their powers and duties.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. In any county of this state it shall be the duty of the justice of the Supreme Court presiding over the courts of said county to appoint six persons, three of whom must be persons who are or have been members or employes of boards of health. A board of commissioners to be known as "The County Mosquito Extermination Commission," inserting the name of the county in and for which the commissioners are appointed. The commissioners first appointed under the provisions of this act in any county shall hold office respectively for the term of one, two and three years, as indicated and fixed in the order of appointment and all such commissioners, after the first appointment, shall be so appointed for the full term of three years; vacancies in the said commission occurring by resignation or otherwise shall be filled by such justice, and the persons appointed to fill such vacancies shall be appointed for the unexpired term only; such persons so appointed, when duly qualified, constituting such commission and their successors are hereby created a body politic, with power to sue and be sued, to use a common seal and make by-laws: the members of any such commission shall serve without compensation, except that the necessary expenses of each commissioner for actual attendance on meetings of said commission shall be allowed and paid. No persons employed by the said commission shall be a member thereof; before entering upon the duties of his office each commissioner shall take and subscribe an oath or affirmation before the clerk of the county in and for which he is appointed, to faithfully and impartially perform the duties of his office, which oath or affirmation shall be filed with the clerk of the county wherein the commission of which he is a member is appointed; every such commission shall annually choose from among its members a president and treasurer, and appoint a clerk or secretary and such other officers and employes as it may deem necessary to carry out the purposes of this act; it may also determine the duties and compensation of such employes, and make all rules and regulations respecting the same. It shall be the duty of the board of chosen freeholders in each county to provide such commission with a suitable office where its maps, plans, documents, records and accounts shall be kept, subject to public inspection at

such times and under such reasonable regulations as the commission may determine.

2. The director of the State Experiment Station shall be a member ex-officio of each commission and shall co-operate with them for the effective carrying out of their plans and work. The said director shall serve without compensation, except that the necessary expenses actually incurred by him in the attendance of meetings of said commissions shall be allowed and paid. He shall furnish the said commissions with such surveys, maps, information and advice as they may require for the prosecution of their work or, as in his opinion, will be of advantage in connection therewith.

3. Every such commission shall have the power to eliminate all breeding places of mosquitoes within the county wherein it is appointed, and to do and perform all acts and to carry out all plans which in their opinion and judgment may be necessary or proper for the elimination of breeding places of mosquitoes or which will tend to exterminate mosquitoes within said county.

4. Said commission shall, on or before the first day of April in each and every year, file, with the director of the State Experiment Station a detailed estimate of the moneys required for the ensuing year, and a plan of the work to be done and the methods to be employed. The said director shall have the power to approve, modify or alter the said estimates, plans and methods, and the estimates, plans and methods finally approved by him shall be by him forwarded to the board of chosen freeholders in each county on or before the first day of May following its receipt.

5. It shall be the duty of the board of chosen freeholders of each county, or other body having control of the finances thereof, to include the amount of money approved by the director of the State Experiment Station, annually in the tax levy; *provided, however,* that in no year shall the amount so raised exceed the amount hereinafter specified, to wit, in counties where the assessed valuations are not more than $25,000,000.00, a sum not greater than one mill on every dollar of assessed valuations; in counties where the assessed valuations are not more than $50,000,000.00, a sum not more than one-half of one mill on every dollar of assessed valuations; in counties in which the assessed valuations are in excess of $50,000,000.00, a sum not more than one-quarter of one mill on every dollar of assessed valuations.

6. The moneys so raised, or so much thereof as may be required, shall be paid from time to time to the said mosquito commission on the requisition of said commission, duly signed and approved by the president and secretary thereof.

7. It shall be the duty of each commission annually, on or before the first day of November in each year, to submit to the director of the State Experiment Station and to the board of chosen freeholders in their respective counties, a report setting forth the amount of moneys expended during the previous year, the methods employed, the work accomplished and any other information which in their judgment may seem pertinent.

8. Nothing in this act shall be construed to alter, amend, modify or repeal the provisions of chapter 134 of the laws of 1906, or alter, amend, modify or repeal any act now existing conferring upon state or local boards of health any powers or duties in connection with the extermination of mosquitoes in said state, but shall be construed to be supplementary thereto.

9. This act shall take effect immediately.

Approved March 21, 1912.

Extract from Chapter 288, Laws of 1915, concerning the State Board of Health: 5 (k) He, the Director of Health of the State of New Jersey, shall be a member ex-officio of each county mosquito extermination and shall co-operate with them for the effective carrying out of their plans and work.

In 1919 Chapter 104, Laws of 1912, was amended to read as follows:

Chapter 123, Laws of 1919

An Act to amend an act entitled "An Act for the establishment of county mosquito extermination commissions and to define their powers and duties," approved March 21, 1912.

BE IT ENACTED by the Senate and General Assembly of the State of New Jersey:

1. Section 4 of the act of which this act is amendatory be and the same is hereby amended so that it shall read as follows:

4. Said commission shall, on or before the first day of November in each and every year, file with the director of the State Experiment Station a detailed estimate of the moneys required for the ensuing year, and a plan of the work to be done and the methods to be employed. The said director shall have the power to approve, modify or alter the said estimates, plans and methods, and the estimate, plan and method finally approved by him shall be by him forwarded to the board of chosen freeholders in each county on or before the first day of December following its receipt.

2. This act shall take effect July 1, 1919.

Approved April 11, 1919.

Under the terms of the above act Hudson, Bergen, Passaic, Essex, Union and Atlantic counties have undertaken the suppression of all species of mosquitoes. Middlesex, Monmouth, Ocean and Cape May counties have given most of their attention to the suppression of the salt-marsh forms.

The New Jersey Mosquito Extermination Association

This state-wide society, organized for the special purpose of furthering anti-mosquito work in the state in all its phases, was formed in the year of 1913 by representatives of the mosquito commissions created under the authority of Chapter 104, Laws of 1912, the State Agricultural Experiment Station and certain interested private citizens. This association has now held seven annual conventions at each of which the status of mosquito work in the United States and various other parts of her world has been presented by men most familiar with them. The association has increased to a membership of over 2100, and each year the proceedings of the annual convention have been published.

Fig. 127. Delegates at the Fourth Annual Meeting of the New Jersey Mosquito Extermination Association (1917), held at the Traymore, Atlantic City.

Summary

At the present time there are three legalized agencies for mosquito suppression. The local and state boards of health operating under the authority of the Duffield Act, the State Agricultural Experiment Station operating under authority of Chapter 134, Laws of 1906, and devoting its attention primarily to the supression of the salt-marsh mosquitoes but also supplying technical assistance to the boards of health and other organizations; the county mosquito extermination commissions, operating under the authority of Chapter 104, Laws of 1912, as amended by Chapter 288, Laws of 1915, and Chapter 123, Laws of 1919, and devoting its attention to the mosquito problem as a whole.

The work of the three organizations is unified by the following facts: (1) that the law enforcement officer, director of the New Jersey State Agricultural Experiment Station designated in Chapter 134, Laws of 1906, is ex-officio a member of all county mosquito commissions and responsible for the nature of the plans, methods and estimates used by them; (2) that this same officer finds it his duty to see that proper technical assistance is furnished to boards of health in their mosquito campaigns; (3) that the director of the State Department of Health is ex-officio a member of all county mosquito commissions and thereby keeps in touch with their activities.

An organiation known as the New Jersey Mosquito Extermination Association has been created in which all anti-mosquito interests can be gotten together and from which the general policies relative to the solution of the problem, can be and are promulgated.

A Brief Analysis of the New Jersey Mosquito Problem

Geographical and Biological Conditions

The first phase of the problem of mosquito control in New Jersey is the elimination of the breeding of the salt-marsh forms. The second phase is the elimination of the breeding of the fresh-water forms.

From the standpoint of mosquito control the area of the state naturally falls into two main divisions. The first includes the coastal edge extending from thirty to forty miles back from the coastline. The second includes all territory of the state surface back of this coastal zone. In the coastal zone the preeminent mosquito problem is the salt-marsh one; but there is a secondary problem which

is concerned with the elimination of the species of mosquitoes that breed in fresh water on the upland. In the territory which lies back of the coastal zone the salt-marsh mosquito problem does not exist, and the problem of mosquito control is concerned only with the forms which breed in fresh water.

Each of these zones may in turn be divided into two natural divisions. The first part of the coastal zone lies north of the sandy areas of the state, begins with the Raritan River and extends northward to the northern end. The second division of the coastal zone begins at the Raritan River and extends southward to Delaware Bay. The fresh-water swamp and the malarial mosquito phases are present in the first division. The house mosquito phase is present throughout both. Consequently, the work in the first section, which may be called the northern end of the coastal zone, must be much more extensive on the upland than is necessary in the second division or the southern portion of the coastal zone.

In the territory lying back of the coastal zone we have a northern division ending with the appearance of light sandy soil and a southern division characterized by the presence of a light sandy soil. In the northern division we have the fresh-water swamp (*sylvestris*) and malarial mosquito phases of mosquito control, while in the southern division they are almost entirely absent. The house mosquito *(pipiens)* phase of the problem is present throughout.

The attitude of the people in these different zones is markedly different. Those who live in the coastal zone, by reason of the tremendous invasions and the consequent suffering occasioned by the salt-marsh mosquitoes, are much more favorably inclined toward mosquito work and are much more willing to support fairly adequate appropriations for work in the suppression of mosquitoes. Furthermore, the coastal zone includes by far the greatest proportion of the population of the state and by far the greatest opportunities for development. The people in the territory lying back of the coastal zone are subject to about the same mosquito annoyance that one finds in inland states of the northern section of the United States. With good screening and fairly early habits of retiring into the house, the effects of the mosquito pest, with a few exceptions, can largely be avoided. The exceptions are found in areas where large swamps are located nearby, or where the malarial species breed abundantly and the disease of malaria is prevalent. In this territory the people do not, on this account, readily support appropriations of adequate size for mosquito control.

The Salt-Marsh Mosquito Preeminent

Obviously it seems that anti-mosquito work should be pushed where it is most greatly needed, and that means that the main work will be done within the coastal zone. Here, as was previously pointed out, the principal problem is the control of the salt-marsh mosquitoes. For a number of years, therefore, the principal anti-mosquito efforts have been devoted to this phase of the mosquito problem.

The methods of handling this problem on the salt marshes of New Jersey, amounting to more than 296,000 acres, are well developed and have been set forth in various publications of the station. The work of treating the salt marshes for mosquito control has now covered more or less completely the territory from the northern end of the state as far south as lower Barnegat Bay. In addition to this the whole ocean front of Atlantic County has been treated and the area lying about Cape May City and northward thereof for a distance of several miles has been drained. All told, there yet remains of the salt marshes to be treated something over 150,000 acres. The vast bulk of this acreage is located in the southern counties of Ocean, Atlantic, Cape May, Cumberland and Salem; but some remains still to be done in certain northern counties, notably Middlesex, Hudson, and Bergen.

Experience has shown that the cost of this operation is about $5.00 an acre representing a total expenditure, if pursued on a large scale, of about $750,000.

Legal Organizations for Suppressing Mosquitoes

There exist in the state today three organizations created by force of law for doing this work. The first is the state and local boards of health which in connection with general health work are empowered to compel the abatement of any water in which mosquito breeding occurs. The second is the New Jersey State Experiment Station and the third is the county mosquito extermination commission. The State Experiment Station has for its phase of the work the task of treating the salt marshes for the control of the salt-marsh mosquitoes as rapidly as the funds appropriated to it by the state will permit, and it has the further duty of furnishing information and plans for the work to the county mosquito extermination commissions. The field of the county commission is the suppression of the mosquitoes which breed within the boundaries of the county which it serves. So far as legal enactment goes the county commission

has reasonably adequate powers to meet the problem within its own county, and the extent of its operations and the degree of protection afforded to the people therein depend upon the funds which it can obtain from the county board of freeholders to carry on this work.

The Salt-Marsh Mosquito Problem too Expensive for Counties, State Should Be More Generous

The vast bulk of the still untreated marsh is located within the limits of counties whose taxable values are such that the sums needed for the treatment thereof cannot be obtained, except as spread over a long period of years. Nevertheless, within these counties there are enormous possibilities of agricultural and urban development, which await the suppression of the salt-marsh mosquitoes for their realization. Once the marshes in question have been treated, the funds which the county mosquito extermination commissions can obtain to carry on their work will be adequate to maintain the ditching systems and to suppress the breeding of the fresh-water species.

This being the state of affairs, it is obvious that if prompt relief is to be obtained and a beginning on the realization of these tremendous agricultural, urban and possibly industrial developments is to be made within a reasonable length of time, funds from some other source than the individual counties must be obtained. In view of the fact that the benefits from such development are certain to be state-wide it is entirely reasonable and proper for the state as such to step in and make the necessary appropriations to carry out and complete the initial work of salt-marsh treatment.

State Should Do Initial Drainage for Control of Salt-Marsh Mosquito, Counties can Maintain Salt-Marsh Work and Attend to Fresh-Water Species

After the state has done this initial work the county mosquito extermination commission will take over the maintenance burden at once and will continue its present work and will be able gradually, as education in mosquito-control matters becomes more general, to take up and control the breeding of all species within the limits of the state in such a fashion that the New Jersey people will not be aware that mosquitoes are about.

Progress Made in New Jersey

The progress made up to the close of 1919 is set forth in the following statement:

Last year (1919) we were able to say approximately 120,000 acres of the salt marsh have been rendered reasonably free from mosquito breeding. This

has involved the cutting of 18,244,217 linear feet of ditches 10 inches wide and 24 to 30 inches deep, or their equivalent, the building of 18.2 miles of dike, the installation of 80 sluice and tide-gates (representing 932 square feet of cross section), and the installation of one 4, one 8, and one 12-inch centrifugal pump. Approximately 60 per cent of the reasonably permanent pools scattered

Fig. 128. Map showing progress of salt-marsh mosquito control.

over 315,000 acres of upland have been permanently eliminated. . . . Approximately 120,000 acres of salt marsh have been patrolled throughout the mosquito season, and the mosquito-breeding destroyed in so far as possible. Approximately 315,000 acres of upland have been likewise patrolled, a large amount

of draining and filling completed and, as nearly as possible, all residual breeding destroyed.

Perhaps the quickest and surest way to set forth the facts regarding the progress in control of salt-marsh mosquitoes is to examine the map of New Jersey (fig. 128). The bordering salt marshes of the ocean and bay coasts are either completely black or cross-barred with black. The former represents untouched salt marsh and the latter the more or less completely drained portions. The original area of upland formerly covered by flights of the salt-marsh mosquitoes is outlined by the dotted lines. That portion of this area which is still infested is shown by dot-shading and the depth of the shading is intended to correspond to the density of infestation.

The occurrence of infested areas in the region of the salt marsh which is marked drained, is due to incompleteness of the drainage systems established. Anything like complete control throughout this large area involves the installation of more complete drainage systems than now exist in more than a very few places. For the purpose of showing the stage of completeness in the drainage systems, the following table of estimates prepared about October 31, 1919, is presented:

Table 3

Status of Salt-Marsh Drainage, October 31, 1919

County	Acreage of tidal marsh	Estimated percentage of the marsh that is drained or does not need drainage
	acres	per cent
Hudson	11,486	64
Bergen	8,378	70
Essex	4,631	100
Union	4,413	93
Middlesex	8,199	56
Monmouth	3,378	97
Ocean	40,400	71
Burlington	9,943	
Atlantic	53,325	65
Cape May	53,638	39
Cumberland	52,661	4
Salem	31,780	

In Bergen, the lower end of Ocean, Atlantic and Cape May, in certain limited areas in other counties, the ground which was covered was sufficiently drained and the percentage marked as undrained represents areas that are practically untouched. In the other counties, however, with the limited areas excepted, the shortage is due to lack of completeness within areas already covered by drainage systems.

The progress in salt-marsh ditching from the beginning is given in table 4.

Table 4

Salt-Marsh Drainage in New Jersey Reckoned in Ditches 10 Inches Wide and 30 Inches Deep

YEAR	Hudson County		Bergen County		Essex County		Union County		Middlesex County		Monmouth County	
	State Experiment Station	County Commission	State Experiment Station	County Commission	State Experiment Station	County Commission	State Experiment Station	County Commission	State Experiment Station	County Commission	State Experiment Station	County Commission
	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet
1902 to 1912	171,350	113,500	.....	.....	217,800	618,000	707,812	372,112	505,800	.....	553,700	237,500
1913	.....	100,000	.....	.....	.....	350,000	.....	25,000	30,000	.....	.....	.....
1914	.....	126,000	.....	.....	.....	.....	25,000	37,385	.....	52,800	.....	245,872
1915	.....	150,000	346,282	155,000	.....	30,098	.....	29,777	.....	116,564	.....	25,000
1916	.....	140,000	.....	150,000	.....	69,057	.....	13,814	.....	186,100	.....	136,003
1917	.....	109,943	.....	.....	.....	30,000	.....	57,941	.....	35,051	.....	46,476
1918	.....	9,665	.....	22,500	.....	10,995	.....	1,500	.....	45,051	.....	7,000
1919	.....	145,488	.....	58,000	.....	39,923	.....	8,000	.....	97,873	.....	22,576
Totals	171,350	894,596	346,282	385,500	217,800	1,147,173	732,812	645,529	535,800	533,439	553,700	720,424
Grand Totals	1,065,946		731,782		1,364,973		1,378,341		1,069,239		1,274,124	

Table 4—(*Continued*)

Salt-Marsh Drainage in New Jersey Reckoned in Ditches 10 Inches Wide and 30 Inches Deep

YEAR	Ocean County		Atlantic County		Cape May County		Cumberland County		Totals Yearly
	State Experiment Station	County Commission	State Experiment Station	County Commission	State Experiment Station	County Commission	State Experiment Station	County Commission	
	feet	feet	feet	feet	feet	feet	feet	feet	feet
1902 to 1912	1,954,380	15,000					630,000		6,096,954
1913	399,842		260,000	404,365					1,569,207
1914			271,601	828,337					1,587,025
1915		30,000		1,325,100	209,634				1,517,455
1916		339,520		1,391,912		132,229			1,558,642
1917	119,285	538,277		323,907	101,987	161,479			1,524,345
1918	137,931	360,097		305,002	137,931	161,479			1,198,252
1919	90,074	336,946		311,324	140,000	116,980			1,367,191
Totals	2,701,512	1,619,840	531,601	4,889,985	589,552	572,177	630,000		18,419,072
Grand Totals	4,321,325		5,421,586		1,161,729		630,000		

With the exception of some drainage carried out very early on the Newark, Elizabeth and Jersey City meadows, all this work has been done by the State Agricultural Experiment Station and the county units. The latter began in 1912. Table 5 shows the relative part played by each.

Table 5

Ditching by Experiment Station and County Commissions

Date	Experiment Station Ditching	County Commission Ditching
	feet	feet
1912	1,000,180*	239,800
1913	689,842	879,365
1914	321,601	1,057,167
1915	713,823	1,971,248**
1916	None	2,542,713
1917	221,492	2,176,492
1918	275,862	912,390
1919	230,074	1,137,117

*Maximum figures, probably 25 per cent too high.

**In 1912 the practice of going over every foot of the entire system obtained. While in 1912 the station was doing 81 per cent of the total drainage, in 1919 it did about 17 per cent. Nevertheless, it must be said that the services of the station have constantly been at the command of the county units, and that the drainage done by it in no adequate way measures the part played by it in the accomplishment of this drainage.

Results of Mosquito-Control Work in New Jersey

There are several criteria for measurement of the result of salt-marsh mosquito control work, such as the presence or absence of mosquitoes, the state of public opinion as reflected in the newspapers and the development of the areas which are normally subject to mosquito flights but which have been largely freed from them.

Effect on Mosquito Prevalence

On two or three occasions during each of the last eight mosquito-breeding seasons, the writer has made a collecting trip down the coast running all the way within a few miles of the coast and stopping to collect mosquitoes at regular intervals. The results of the July, 1917, collections which are shown graphically in figure 129 are rather worse than those usually obtained because they show more mosquitoes in the northern end of the state than is usually the case.

All collections were made in shrubbery or tall weeds in broad daylight. All collections were the work of two collection bottles. When the total catch in 5 minutes reached 30, the limiting factor became the length of time necessary for the bottles to kill.

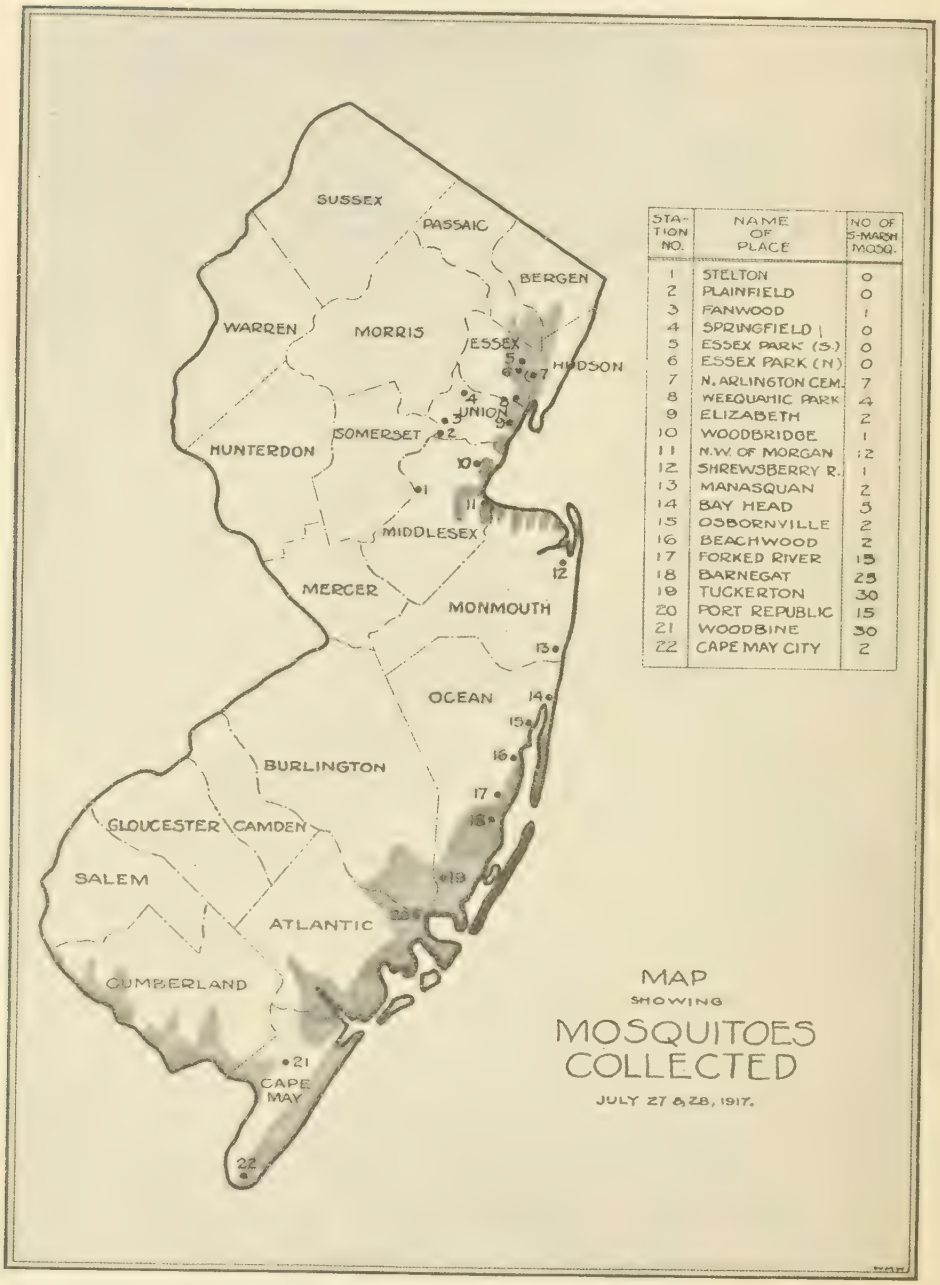
Table 6

Mosquitoes Collected July 27 and 28, 1917

Station Number	Name of Place	County	Number of Salt-Marsh Mosquitoes
1	Stelton	Middlesex	0
2	Plainfield	Union	0
3	Fanwood	Union	1
4	Springfield	Union	0
5	Essex Park (South end)	Essex	0
6	Essex Park (North end)	Essex	0
7	North Arlington Cemetery	Hudson	7
8	Weequahic Park	Essex	4
9	Elizabeth	Union	2
10	Woodbridge	Middlesex	1
11	Just northwest of Morgan	Middlesex	12
12	Shrewsberry River (North branch)	Monmouth	1
13	Manasquan	Monmouth	2
14	Bay Head	Ocean	5
15	Osbornville	Ocean	2
16	Beachwood	Ocean	2
17	Forked River	Ocean	15
18	Barnegat	Ocean	25
19	Tuckerton	Ocean	30
20	Port Republic	Atlantic	15
21	Woodbine	Cape May	30
22	Cape May City	Cape May	2

The collection at North Arlington Cemetery was made at the edge of a bad breeding marsh. The collection near Morgan was made near a piece of undrained salt marsh. In Ocean County the mosquitoes from the large undrained areas to the south were met in increasing numbers from Forked River as the writer went south until the full density of the brood was reached at Tuckerton. Port Republic was like the rest of the Shore Road, beside drained marshes but in reach of flights from undrained meadows. At Woodbine the full density of the brood was found. The marshes in the neighborhood of Cape May City are drained and the mosquitoes must come in on a northeast or northwest breeze, neither of which usually are suitable for their carriage.

It must be remembered that the trip from which these records are derived was made during the part of 1917 when combinations of high tide and heavy rainfall gave the best possible mosquito-breeding conditions, and that normally the catch of salt-marsh mosquitoes in the northern parts of the state, where from 1 to 5 were taken, would have shown practically nothing.



STATION NO.	NAME OF PLACE	NO OF 5-MARSH MOSQ.
1	STELTON	0
2	PLAINFIELD	0
3	FANWOOD	1
4	SPRINGFIELD	0
5	ESSEX PARK (S.)	0
6	ESSEX PARK (N)	0
7	N. ARLINGTON CEM.	7
8	WEEQUAHIC PARK	4
9	ELIZABETH	2
10	WOODBRIDGE	1
11	N.W. OF MORGAN	12
12	SHREWSBERRY R.	1
13	MANASQUAN	2
14	BAY HEAD	3
15	OSBORNVILLE	2
16	BEACHWOOD	2
17	FORKED RIVER	15
18	BARNEGAT	25
19	TUCKERTON	30
20	PORT REPUBLIC	15
21	WOODBINE	30
22	CAPE MAY CITY	2

Fig. 129. Map showing mosquitoes collected July 27 and 28, 1917.

With these facts in mind, the reader should note the correlation between drainage and the absence of mosquitoes. Opposite the drained marsh, unless within flight range of the undrained areas, the salt-marsh mosquitoes caught were few or none, while along side of the undrained marsh the catch was many times larger.

With few exceptions the newspapers throughout the state have supported and expressed appreciation of the work and have opposed any emasculating of the laws governing it. Practically without exception the newspapers located within the limits of counties where the work is going on have heartily supported the effort.

Effect on Industry

The work of the mosquito control has now gone far enough to show some striking results in the way of industrial development.

In Essex County, as a whole, the increase in taxable values from 1896 to 1918, inclusive, has shown a steady increase from 187 million to nearly 800 million. With the exception of 1906, the differences in percentage of increase from year to year have been so small as to render them attributable to slight changes in property classification. In 1906 we find a 56 per cent increase which is probably due to the inclusion of railway properties. On the Newark meadows, however, we find a very different story. In the period from 1896 to 1905, inclusive, there was either no increase in ratables at all, or only a fraction of 1 per cent. The sharp increase in 1906 is probably due to the same cause as the increase in the county as a whole; but from 1906 on to the present, in every year we find an increase, and throughout the period we find an average increase of 25 per cent, as compared with an average increase of 8 per cent in the county for the same period.

Table 6 gives the total ratables (net valuation taxable) for Essex County for each year, with the annual per cent of increase, from 1896 to 1918, inclusive, and gives by years the total ratables of the Newark meadows, from 1896 to 1919, inclusive.

The increase in valuations for Essex County from 1905 to 1918 is 380 per cent; the increase in the ratables of the Newark meadows for the same period is 3117 per cent, or more than 8 times the increase for the county.

In 1905, just preceding this upward trend, the state and local authorities began their efforts to bring the salt-marsh mosquito under control. Since that time, thanks to local interest which finally culminated in the formation of the Essex County Mosquito Exter-

mination Commission, the work of treating the marshes in such a fashion as to eliminate the breeding of this pest has gone steadily forward. No one can escape the fact that this large upward trend of the taxable values of the Essex County salt marshes has been coincident with the progress of the work against the salt-marsh mosquito. In view of the testimony from factory owners and oper-

Table 7

Increase in Taxable Values in Essex County

Whole of Essex County			Newark Meadows		
Ratables (Net Valuation Taxable)	Increase Over Preceding Year	Year	Ratables (Net Valuation Taxable)	Increase Over Preceding Year	Tax Produced
	per cent			per cent	
$187,007,043	..	1896	$390,335	..	$7,650
192,169,150	2	1897	385,335	—1	7,642
195,451,005	1	1898	323,999	—15	6,804
203,398,739	4	1899	323,655	—0.1	6,861
210,806,331	3	1900	323,850	0.06	7,253
222,165,236	5	1901	323,385	—0.1	6,920
230,197,268	3	1902	320,562	—0.8	7,116
237,172,475	3	1903	320,697	0.04	7,440
245,671,200	3	1904	320,492	—0.06	7,275
266,539,637	8	1905	322,892	0.7	7,298
415,838,528	56	1906	460,140	42	8,016
440,815,139	6	1907	545,565	18	9,241
442,789,444	0.4	1908	658,480	20	10,750
485,615,926	9	1909	726,985	10	13,896
516,235,469	6	1910	758,670	4	14,653
552,035,863	6	1911	1,113,465	46	21,948
583,870,154	5	1912	1,428,525	28	29,153
606,478,552	3	1913	1,735,610	21	35,071
621,744,370	2	1914	2,192,685	26	45,651
646,289,876	3	1915	2,251,355	2	51,367
653,741,287	1	1916	3,750,885	66	91,910
686,361,004	4	1917	4,764,065	27	128,668
710,785,536	3	1918	6,500,890	36	188,539
		1919	7,015,110	7	238,513

ators in this district, and in view of this coincidence of mosquito-control work and large increases in taxable values, it is hard to escape the conclusion that mosquito control has played a considerable part in this increase in land values.

While the Newark meadows have been selected for illustration because the permanent mosquito eradication work is more nearly complete there than elsewhere in the metropolitan district, the same relatively enormous increases in ratables is found on other meadows where the control work has advanced far enough to be considered a factor in real-estate values.

Probably other instances equally or more striking could be found, did time permit the making of the necessary studies. One would be especially likely to find instances in that portion of the shore reclaimed within the past half-dozen years.

One can gain a pretty good notion of the effect of mosquito suppression on the development of property by driving southward along the coast from Jersey City. At the points where the mosquito pest assumes its original strength, the houses and other buildings, with a few exceptions, take on a weather-beaten and tumble-down appearance, and the farms exhibit a neglected look. Even in the cursory examination such a trip affords, there is clear evidence that there is less good farming in the districts that are still heavily infested than in sections that have been rendered practically free of the mosquito pest.

Cost of Mosquito Suppression in New Jersey

The work of mosquito control has now gone far enough to justify an attempt to summarize its cost.

Without doubt the cost of mosquito control per square mile of area increases with the density of population, because every family, through the employment of water-holding receptacles, increases the ability of a given amount of land surface to produce mosquitoes both in the actual water-breeding surface and through pollution. At the same time, of course, natural breeding places are reduced in area through draining and filling incident to agricultural, industrial, and urban development. But such areas as are left are rendered more prolific producers through pollution with human and animal waste. Theoretically, the state should be reached when the sanitary arrangements incident to the maintenance of the health of extremely dense populations should almost, if not quite, eliminate all breeding places for mosquitoes. Nowhere in New Jersey has this stage been even approximated.

From table 8 it is evident that, while the total cost per square mile increases with the density of the population, the per capita cost and the percentage charge against taxable values decreases as the population increases.

The geography of each county differs to such an extent that one cannot compare the charges for the work in one county with those in another except in the most general way.

In table 9 the percentages devoted to each type of work are interesting. Of course, the prime object in every county is, af-

Table 8

Estimates of the Cost of Mosquito-Control Work by The County Commissions

County	Land Area—Square Miles	Resident Population, 1915 Census	Population Per Square Mile, 1915	Total Ratables, 1918	Amount Collected for Mosquito-Control Work in 1918	Amount Per $1000 of Ratables in 1918	Population Protected in 1918	Per Capita Cost in 1918	Area Protected in 1918—Square Miles	Cost Per Square Mile in 1918	Number of Years Commission has been at Work	Total Expenditures
Hudson	43	571,371	13,288	$681,027,425	$33,000	$0.048	571,371	$0.057	43	$684 90	6	$177,060
Bergen	186	138,596	998	500,737,427	24,000	0.119	178,596	0.132	182	131 75	4	76,000
Essex	126	566,324	4,495	710,785,556	67,265	0.094	566,324	0.118	126	533 85	4	406,845
Union	103	167,232	1,624	203,885,361	26,565	0.133	167,232	0.158	105	253 48	4	243,976
Middlesex*	312	144,716	461	113,309,363	6,500	0.057	135,000	0.048	311	.....	5	31,510
Monmouth*	472	107,636	225	122,131,375	6,000	0.049	58,000	0.055	125	.....	4	26,619
Ocean*	638	32,011	46	14,296,808	10,000	0.411	25,000	0.40	500	.....	4	33,000
Atlantic	569	82,840	146	127,130,179	26,000	0.204	400,000	0.065	450	.....	4	139,503
Cape May*	255	24,909	96	38,800,210	10,000	0.258	10,000	1.00	10	.....	3	30,000
Passaic	195	236,264	1,206	216,993,487	16,022	0.073	221,000	0.073	36	388 46	5	75,263
Morris	475	81,514	172	59,908,879	2,000	Survey work only						1,151

*These counties are attempting to control salt-marsh mosquitoes only.

Table 9

Principal Items In the Cost of Mosquito-Control Work By The County Commissions During 1918

COUNTY	New Permanent Drainage System		Maintenance of Drainage Work		Temporary Eliminaton Work		Inspection		Administration	
	Cost	Per Cent of Appropriation	Cost	Per Cent of Appropriation	Cost	Per Cent of Appropriation	Cost	Per Cent of Appropriation	Cost	Per Cent of Appropriation
Hudson	$8,485 06	25.7	$2,341 64	7.1	$2,882 67	8.7	$8,308 25	25.2	$2,347 86	7.6
Bergen	10,025 26	41.7	2,609 63	6.6	993 38	3.9	2,957 40	12.3	3,101 00	12.5
Essex	*22,515 37	33.5	*17,367 81	25.8	8,543 86	12.7	13,273 10	19.0	5,564 76	8.3
Union	4,693 19	17.0	11,280 05	42.0	.....	.....	4,020 50	16.0	2,537 76	10.0
Middlesex	1,729 04	26.6	1,025 95	16.7	149 97	2.3	320 27	4.9	1,730 63	26.6
Monmouth	*560 00	8.7	*5,440 00	90.6	701 00	11.6	1,863 00	31.0	183 00	3.0
Ocean	6,531 77	65.0	*2,500 00	25.0	.....	.....	725 00	7.2	243 23	2.4
Atlantic	6,701 16	29.5	4,199 51	16.1	264 17	17.7	3,771 72	14.5	4,018 76	17.7
Cape May	8,700 69	87.0	*1,167 61	11.6	.....	.....	866 00	8.0	1,594 14	15.0
Passaic	Survey work only		.....	.....	2,704 65	19.3	5,342 10	38.9	3,967 20	28.3
Morris	Survey work only		.....	.....	.....	.....	.....	.....	.....	.....

*Including overhead.

Table 10

Cost of Salt-Marsh Mosquito-Control Work By The County Commissions in 1918

COUNTY	New Drainage				Maintenance			
	Number of Acres Drained	Total Cost	Cost Per Acre	Per Cent of Appropriation Expended for New Drainage	Number of Acres on which Drainage Systems were Maintained During 1918	Total Cost of Maintenance	Cost Per Acre	Per Cent of Appropriation Expended on Maintenance
Hudson	2,135	$8,485 06	$3 98	25.7	4,975	$2,341 64	$0 47	7.1
Bergen	500	3,119 29	6 24	13.0	5,300	1,252 63	0.24	5.2
Essex	.....	**12,191 29	2 70	18.1	4,500	**9,298 50	2.06	13.8
Union	.....	2,781 92	.....	10.0	3,300	**3,212 92	0.87	12.0
Middlesex	1,746	1,729 04	0 99	26.6	2,754	1,025 95	0.35	16.7
Monmouth	65	*520 00	8 00	8.7	3,213	*5,140 00	1.59	85.0
Ocean	1,600	*6,531 77	4 08	65.0	24,000	*2,500 00	0.11	25.0
Atlantic	1,124	6,701 16	5 98	29.5	17,632	4,199 51	0.23	16.15
Cape May	6,400	*8,700 69	1 54	87.0	14,080	*1,167 61	0.09	11.6

*Including overhead.

**Additional new drainage, in part made necessary by the industrial development of the meadows, installed on areas already ditched or diked.

ter giving the best immediate protection possible, to accomplish the largest possible amount of permanent draining and filling. In counties just beginning or in which the work has just recently begun, the percentage of permanent work is bound to be high. This is especially true in counties having large and untreated marshes because there is no hope of affording immediate relief in any other way. As more and more of the permanent drainage work is done the opportunities for giving immediate protection to larger numbers of people are increased through the extension of permanent work, and the percentage devoted to temporary elimination will increase until such a time as the permanent work has covered the area.

Here again it should be pointed out that the geographical features of each county are so different from those of other counties that only the most general comparisons are justified.

The acre cost of salt-marsh drainage and the acre cost of maintenance in table 10 are particularly interesting. Unfortunately, it has been impracticable from the data to determine the number of feet of drainage per acre.

Except in the case of Middlesex, where private and government funds were used, the acre cost without doubt depends primarily upon the footage installed and the differences in acre cost are mainly chargeable to that figure. Experience of the station has shown the average acre cost of installing 300 linear feet of open salt-marsh trenching is $5.00, reckoned on the basis of a ditch approximately 10 inches wide by 30 inches deep.

The acre cost of maintenance depends, in open meadows, on the number of linear feet per acre. On enclosed marshes the gain in the absence of blockage by floating sod and rubbish is compensated for by the lack of natural cleaning through the scouring action of tidal suck, the charges for dike and tide-gate repairs and the application of oil to mosquito-breeding in ditches.

Here again it must be pointed out that the geography of salt marshes varies to such an extent in different counties as to render only the most general comparisons justifiable.

Education in mosquito-control matters has proceeded from the northern end of the coastal zone (an area extending from the coastline 30 to 40 miles inland) southward. Burlington has been found to be particularly difficult to interest because the salt-marsh end of the county is dominated by the western side where the salt-marsh mosquitoes do not reach. Cumberland and Salem will naturally be the last to be affected by the natural movement of this educational

work because the information passes most readily from the counties in which work is going on, to counties adjacent.

The counties lying back of this coastal zone will be still more slow to take up the work because that great persuader, the salt-marsh mosquito, is not present.

What Remains To Be Done

Having set forth what has been accomplished, let us consider what remains to be done.

Basing the calculations on the table of the estimated degree of completion of salt-marsh drainage in each county, drainage enough to cover about 13,374 acres, not to mention dikes, tide-gates and pumps, is needed in the counties of Hudson, Union, Middlesex and Monmouth. To this must be added about 12,000 acres in Ocean, nearly 10,000 in Burlington, about 20,000 in Atlantic, about 45,000 in Cape May, 52,661 in Cumberland and 31,370 in Salem, making a total of 184,815 acres. Of these 184,815 acres about 35,000 either are now or have been at some time under dike for agricultural purposes but the sea has reclaimed so large a proportion of it that it should be considered as territory to be drained. Of this total area, probably about 20 per cent will not need drainage, leaving about 150,000 acres that must be drained, costing under present conditions about $750,000.

At the present rate of 10,000 acres opened with 300 feet to the acre, 15 years will be required to complete the initial drainage of the salt-marsh.

Naturally the problem of maintenance follows the establishment of salt-marsh drainage systems. At the end of 1919 about 18,000,000 linear feet of ditching 10 inches wide and 30 inches deep, or its equivalent, had been cut on the salt marshes of the state, all of which, with the exception of a small amount in Cumberland County, has been for the last few years maintained by the county mosquito commission. When the initial drainage will have been completed it is estimated roughly that there will be 70,000,000 linear feet of 10 by 30-inch ditching, or its equivalent, on the salt marshes. Of this total we may say that, because of short length and strong tidal outlets, 20 per cent will never require attention other than blockage removal and the clearing of overgrowing sides. The remaining 80 per cent will have to be cleared every third year, or 18,662,000 linear feet each year. Experience has shown that the average cost for such

work should not exceed ⅓ of a cent per foot, which would make the cost about $62,000.00 annnually. To this must be added the cost of blockage removal for the rest of these systems, which experience has shown to amount to about $800.00 per million feet, which would amount to $48,800.00 annually. Thus the annual cost of keeping the ditching systems in repair should amount to about $110,800.00, or about 37.4 cents per acre.

Of course, when dealing with salt marshes in close proximity to average populations a higher degree of protection will be demanded, and the cost of maintenance will be much higher.

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